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SOCIAL DOMINANCE AND SEXUAL STATUS IN THE CHIMPANZEE

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IN THE spring of 1938 I conducted a survey of the adult and adolescent population of the Yale chimpanzee colony at Orange Park, Florida, to test the ability of the animals to respond appropriately to a visual situation after delay and change in the spatial relations of the stimulus objects. My primary interest was in the discovery of the representational process which is basic to the development of any form of language. Previously, in working with young chimpanzees, we had observed that in the absence of the spatial factor delayed response is extremely difficult (Yerkes and Yerkes, 1928; Nissen *et al.*, 1938). It seemed possible that representational processes might be more common or more highly developed in the adult than in the immature ape. Therefore this investigation, which is part of a systematic attempt to discover the pre-human fundament of linguistic process and to trace the phylogenesis of language in the Order Primates.

For this inquiry the simplest experimental situation practicable was sought (cf. Fig. 1). Two rectangular wooden food-boxes, the one white, the other black, each with a convenient handle and a hinged lid, served as stimulus objects. The subject, confined in its living cage behind walls of wire netting, 2-inch mesh, was allowed to watch the experimenter place a piece of apple in the box on the animal's right and before it. This might be either the white or the black box. Then, behind a screen, the two boxes were shifted in relation to one another and immediately presented before the cage, about 50 cm. apart, in such manner that the subject might indicate its choice by opening the box in which it expected to find the apple. The animals were neither isolated nor placed in a special observational cage, but instead were used just as they happened to be located, which was mostly in associated pairs.

In what follows we shall consider not the evidences bearing on representational process and response, but instead a by-product of the experiment, to wit: certain variations in the social behavior of pairs of subjects and the discovery of correlated or causal psychobiological factors. For,

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as it happened, it was my good fortune to present to my subjects an experimental situation which served admirably to exhibit a major pattern of social relationship, together with at least some of its essential conditions. This cannot better be made clear to the reader than by describing examples of fluctuating social relationship which early in the investigation thrust themselves upon my attention and stirred my curiosity.

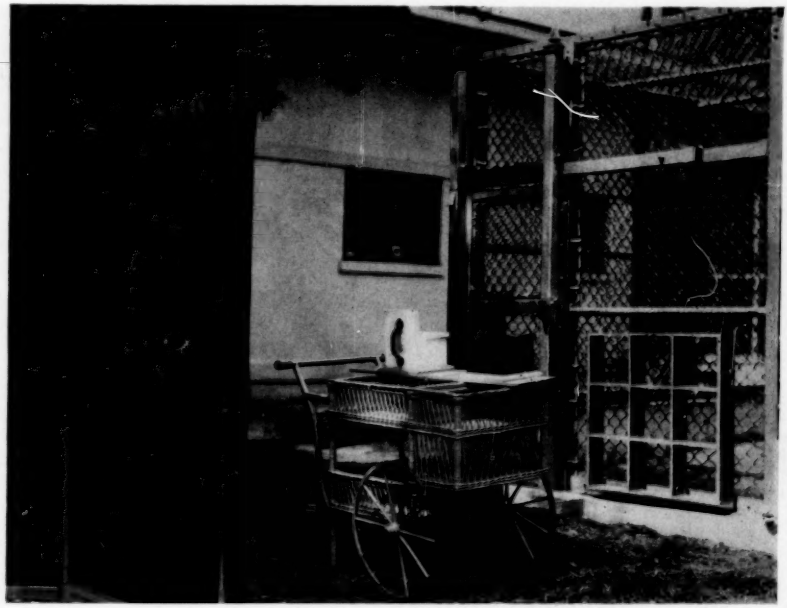

FIG. 1. WHITE AND BLACK FOOD BOXES ON CONVEYOR BEFORE ANIMAL CAGE
In the background appears the opaque screen behind which the boxes were shifted in relative position.

SOME ILLUSTRATIVE OBSERVATIONS

The multiparous females Wendy and Nana (see Table 1), each with a nursing baby about four months old, constituted one of my pairs of subjects. They were entirely friendly, old acquaintances. In the experiment Wendy initially assumed priority of response and took the lead whenever opportunity offered. Nana was definitely subordinated to Wendy's desires and usually would not approach the cage panel before which the boxes were presented until Wendy had completed her trials and left the front of the cage.

For days Wendy had been consistently dominant; Nana, unprotestingly subordinate. Then, suddenly, on May 21st, a new pattern of behavior appeared. Wendy came as usual when the boxes were presented, but instead of choosing between them she tried to raise the lids of both boxes simultaneously, and when prevented she refused to respond and allowed Nana to take her place. This behavior was so at variance with what had gone before, and the change was so abrupt, that I was surprised and puzzled. It was as if an idea which she wished to try out in the

experimental situation had occurred to Wendy. Interestingly enough, she continued wholly good-natured, patient, calm, eager for the apple, and friendly toward both cage companion and experimenter.

The experiment was necessarily omitted May 22d, and when on the 23d Wendy was again given opportunity to respond to the boxes she hesitated, delayed, and finally let Nana come between her and the boxes and open one of them. Whereas previously it had looked as though she were testing the value of a new method of problem solution, it now appeared that she wished, or at least was willing, to give first place to Nana. And in fact it became clear on subsequent days that the dominance-subordination relation had been reversed, for Wendy continued to yield priority of response to Nana and in varied ways accorded her privilege.

As Wendy's behavior inevitably stimulated my curiosity, I turned in my search for an explanation to the results with other pairs of subjects and discovered analogous variations in the dominance relationship.

Thus the congenial multiparous females Pati and Dita, who for years had been intimates, exhibited fluctuation in priority and privilege. During the early days of my experiment Pati asserted leadership and Dita calmly took second place. The social relationship was at once definite and predictable. A variation in this pattern of behavior appeared on May 23d. When I came to their cage to test them, Pati and Dita were lying together on the floor engaged in what appeared to be sexual play. Called to come for the experiment, Pati unwontedly delayed. After a few seconds she arose and started toward me, but Dita clung to one of her legs and she broke away slowly and with evident reluctance. Finally Pati came and began to make response. Her second trial was incorrect, but instead of complaining or screaming in resentment, as ordinarily would have happened, she quietly gave Dita opportunity to take her place. Contrary to my previous observations, Dita at once hastened to the front of the cage and there responded freely, correctly, and as if by right. Pati offered no objection, and while thus yielding privilege to Dita she was calm, gentle, and good-natured. Dita, as if fully realizing the change in her social status, acted as though it were her natural right to take precedence of her companion. This fluctuation in social relationship is no less surprising than that exhibited by Wendy and Nana. But, before explanation is sought, yet another instance of reversal of dominance will be presented.

This time it is between mates. The mature male Bokar and the mature but nulliparous female Bentia constituted a pair of experimental subjects. From the first Bokar assumed priority of response, and so strong was his dominance over the female that as a rule she would not venture to come to the boxes when he was near. Because of this I finally gave up trying to experiment with her, and for several days I worked with Bokar only. On May 21st, as I prepared to present the boxes, Bentia offered herself sexually to Bokar and was accepted. Immediately after the completion of copulation, she took her place beside him in readiness to respond to the boxes. Bokar made no protest. Surprised by the new pattern of social behavior, I decided at once to test the male's patience, so when he raised the lid of the food-containing box I handed the apple to Bentia instead of to him. She took it as if by right, and he patiently awaited his next trial. Each subject completed its series of trials as if on terms of equality with the other.

On succeeding days, although Bokar rarely delayed sufficiently to permit Bentia to take first place in the experiment, she, after presenting sexually and being accepted, seemed to have perfect confidence in his gentleness and good nature, and would crowd in beside or even in front of him and attempt to open one of the boxes and secure the apple. If not actually dominant, she had in any event achieved a degree of privilege which precludes use of the term subordination. Evidently Bokar's dominance either was markedly lessened or temporarily in abeyance.

These three instances of marked variation in the dominance relationship appeared almost simultaneously in the delayed response experiment. As a matter of course I immediately sought some common factor in subject or environmental situation which might serve as explanation. Examination of my observational data revealed the sexual swelling in one of the subjects as a condition common to all cases. And since neither in the experimental situation itself nor in the environing circumstances was I able to discover any common factor which could be correlated with the change in pattern of social behavior, I proceeded with further inquiry into the significance of changing sexual status. The following facts are pertinent.

It will be recalled that Wendy and Nana were lactating females with babies. Ordinarily, under these circumstances, the chimpanzee neither menstruates nor exhibits periodic genital swelling. During the period of my experiment, Wendy showed no obvious fluctuation of sexual status and there was no evidence of cyclical swelling. But Nana, on the contrary, on May 22d, following two days of tumescence of the genital area, was recorded as in maximal swelling. It was at this time that Wendy's relation to her, as exhibited by my experiment, changed abruptly and Nana became leader instead of follower. One may suspect that the social privilege so abruptly accorded Nana resulted from Wendy's response to the immediate sexual phase of her companion. When her genital swelling subsided, Nana again became definitely subordinate to Wendy.

As for Pati and Dita, both were mature, non-pregnant females, subject to recurrent five-week sexual cycles. Both had been nursing infants until about six weeks prior to my observations. Dita's infant was taken from her March 28th and Pati's on March 30th. In neither did sexual swelling occur during the period of lactation, or between the weaning of the infant and the beginning of my experiment. In my period of experimentation Dita exhibited neither menstruation nor marked genital swelling, whereas Pati, after five days of tumescence, achieved maximal swelling on May 21st. It was at this time, and only during the swelling phase of her cycle, that her dominance over Dita weakened and she granted her varied privileges. Under these circumstances Dita tended to assume toward her sexually receptive companion the rôle of male in their homosexual behavior. At no time did Pati yield priority of response to Dita; she merely permitted her certain social liberties and freedom of initiative. This occurred only during Pati's brief period of maximal sexual excitability and receptivity.

The case of Bokar and Bentia is subject to the same hypothetical explanation. Bentia menstruated April 29th; from May 11th to 17th she was recorded as tumescent, and on the 18th as in maximal swelling. It was on the 21st that in the experimental situation I observed her to offer herself sexually to her mate and immediately thereafter to claim and receive privilege. This modification of the

social behavior pattern continued as long as the female was in the phase of genital swelling. Prior to this phase Bokar had ignored Bentia sexually. After the swelling disappeared and Bentia was again sexually non-receptive, the male became indifferent to her, resumed his former dominance, and on a few days, while awaiting the presentation of the boxes, masturbated by rubbing against the cage floor. Bentia, at this time markedly subordinate to her mate, was extremely cautious and timid in the experiment, as if fearful of antagonizing and provoking him to violence. So long as she was sexually acceptable to the male, this female could, and at times quite clearly did, exchange sexual coöperation for the privilege of working on equal terms with her mate in my experiment.

Common to the three cases which have been selected for detailed and illustrative description because of their diversity and simultaneity of appearance, is the fact that pronounced alteration in the social behavior pattern of dominance-subordination occurred during the phase of maximal genital swelling. It should be remarked as a significant fact, which is well established by observations in these laboratories, that the female chimpanzee is sexually receptive and acceptable to the male only during this phase of the sexual cycle, or for a limited portion of it. It further appears that the period of greatest sexual excitability, or oestrus, occurs toward the end of maximal swelling (Yerkes and Elder, 1936).

PRIMATE DOMINANCE AND MASCULINITY

Before we consider further the results of this investigation, I should like to present certain facts, assumptions, and questions relative to primate dominance and sex.

As a conspicuous feature of behavior, dominance has long been known in many types of primate, whereas recognition of its social significance and useful accounts of its characteristics and relations are recent. Zuckerman (1932) definitely established its importance as principle of social organization in the baboon; Carpenter (1934) revealed its virtual absence in the howler monkey, and the frequent occurrence of communistic behavior; and Maslow (1936), after demonstrating its occurrence in several genera of primates, states: "We need feel no hesitation about concluding that dominance is an extremely important determiner of social and sexual behavior in the monkey" (p. 275).

Although thus far it has not been adequately described, the dominance relationship appears frequently in the social behavior of the chimpanzee. I have long found it convenient to use in my records of observation the expression "dominance-subordination" (Yerkes, 1925, p. 155). A working definition is in point. In the present report, dominance implies simply priority of response and ability to delay or inhibit the response of a companion. This, however, is not an adequate descriptive definition of the phenomenon, for the dominant chimpanzee generally assumes also the right to satisfy any or all needs, desires, or whims before permitting a companion to do likewise. Less predictable is the assumption of leadership and initiative in safeguarding social welfare.

Dominance has come to be associated with masculinity, and subordination with femininity, in mammalian behavior. The validity of this association for the chimpanzee may be questioned, since dominance behavior is exhibited by females as well as males and seems to be linked rather with temperament and physique than with sex characters. Moreover, it has not been proved that in the naturally dominant

female the trait is less strongly developed than in the comparable male. For these reasons it is likely to prove far more profitable to seek the facts relative to the nature and relations of dominance-subordination in chimpanzees than to accept what may turn out to be myth or misinformation.

In lieu of adequate information, the following questions may aid us in our efforts to evaluate and interpret the observational materials of this report. Presumably the queries are as applicable to the behavior of man as of chimpanzee.

1. Are the assemblages of psychobiological traits to which the terms masculinity and femininity are applied determined primarily by heredity or by social environment? Have we perhaps tended to ignore or underestimate the influence of culture versus genes in the development of those behavioral patterns which appear to differentiate the sexes? Manifestly certain structures and functions of male and female are hereditary. Is it not equally clear that hormones and individual experience tend throughout life to establish or modify sex traits (Terman and Miles, 1936)?

2. Should either or both masculinity-femininity and dominance-subordination be described as continua, that is, single series of psychobiological values, or are they instead, as certain authorities assume, discrete psychobiological entities, each with constituent parts and relations which do not appear in the other?

3. Are dominance and subordination, which in this connection I assume to designate two different behavioral patterns, demonstrably hereditary?

4. And, if the answer to the above be affirmative, are they sex-limited, or is every individual irrespective of sex by nature either dominant or subordinate, and does its rôle in a given social situation depend on previous experience and the immediate circumstances? The latter question is pertinent because it is definitely established for the primates that the same individual may be dominant at one time, subordinate at another.

In formulating these questions I have had constantly in mind psychobiological instead of morphological sex characteristics.

Current knowledge and understanding of the sexual behavior of primates from monkey to man are entirely inadequate for present theoretical and practical needs, by reason chiefly of their incompleteness and inaccuracy. By comparison with problems of "learning," relatively little attention has been given by psychobiologists to inquiry into the problems of sex. Especially valuable in their many bearings on the observations and conclusions of this report are the pioneer exploratory studies of the sexual life of monkeys and baboons by Hamilton (1914) and Kempf (1917), and the painstaking description of the development of sexual behavior in the young chimpanzee by Bingham (1928). Hamilton and Kempf, both psychopathologists, with therapeutic interests and concern about the validity of psychoanalytic findings, assumptions, and interpretations, made signally important discoveries and suggestions. The adult patterns of chimpanzee sexual behavior which are of special importance to us in this study may be described by reference, since we have already published from these laboratories accounts which go far toward completing the genetic inquiry so well begun by Bingham. In the following reports much information relative to sexual behavior and its relations may be found: Tinklepaugh (1933, 1933a), Yerkes and Elder (1936), Yerkes (1939).

For readers who are not familiar with the principal features of the chimpanzee

sexual cycle, the following description may be serviceable. The duration of the cycle is approximately five weeks (Elder and Yerkes, 1936). Its externally observable phases number six: the menstrual, postmenstrual, tumescent (during which the tissues about the vagina and anus swell), maximal swelling, detumescent, and premenstrual. At its maximum the genital swelling usually is very conspicuous, and throughout the cycle changes in the color, tension, and volume of the genital area are readily observable. Therefore, it is relatively easy to follow the course of a cycle by daily observation and to date important events. For this, among other reasons, the female chimpanzee is eminently serviceable in various studies of sex and reproduction. According to our present data, ovulation in this primate occurs some fourteen days before the beginning of the next menstrual cycle and at or near the termination of maximal genital swelling (Elder, 1938).

THE OBSERVATIONAL SITUATION AND PROCEDURES

The environmental setting of this inquiry was eminently suitable for experimental work on problems of behavior, but even more important, for success in this particular investigation, was the nature of the chimpanzee subjects. All males (three) were mature and experienced as mates; all females were either sexually mature (fifteen) or in late adolescence (four). These apes had been in use in the laboratory-colony for three to thirteen years. For each a record was available in the laboratory files, which included the developmental, sexual, reproductive, disease, and experimental histories. In the case of adolescent and mature females, daily observation of sexual and reproductive status was a part of the record. Chronological age either was known by date of birth or estimated from reasonably adequate growth norms and knowledge of the developmental history and growth vicissitudes of the individual. Almost without exception these animals were known to the observer with respect to psychobiological traits and social relations. Such information, it should be unnecessary to remark, is indispensable if behavioral observations are to be correctly interpreted and advantageously used for comparisons. Without it efforts to describe sexual behavior and to determine the relations of sexual status to such phenomena as those of dominance and subordination are futile.

The subjects are listed, with essential items of information, in Table 1. Members of experimental pairs appear in the horizontal lines, the dominant individual at the left, the subordinate at the right. For descriptive convenience and easy reference, the pairs have been arranged in four categories, which are based upon sex and reproductive status: (1) mates, (2) mature females, (3) mature and immature females, and (4) immature females. Except as indicated, all subjects are female. The only immature individuals are so indicated, either by the abbreviation "Im." following the name or by the classificatory category.

The experimental situation offered the pair of subjects immediate opportunity to respond to the presentation of concealed food and to compete, in accordance with their natural and acquired social-response sendencies, in trying to secure it. To be ture, the food-seeking response was made amidst certain uncontrolled variables in the environment: the activities of other members of the colony, of men about the buildings, meteorological conditions, not to mention variables from day to day in the psychobiological condition and affective relations of the subjects themselves.

Observations were made during May to July, 1938. The study of non-positional delayed response had been in progress somewhat more than a fortnight before I realized that other interesting responses than those I was recording were appearing, and that in neglecting them I might miss an excellent opportunity to discover facts and principles of chimpanzee social behavior, and incidentally to help make sociology experimental! Immediately I designed a record form to enable me quickly to describe what appeared to be important features of social response which were exhibited in my experiment. This record form, as appears from the sample series of observations in Table 2, provides for the entry of the names of subjects, date, sexual status, dominance or subordination response, priority of

TABLE 1

Pairs of subjects

DOMINANT			SUBORDINATE			NO. OF OBS.
Name	Age 1/1/38	Weight 6/1/38	Name	Age 1/1/38	Weight 6/1/38	
			Mates			
	Yrs.	*Kg.*		*Yrs.*	*Kg.*	
Bokar ♂	13	47.2	Bentia	12	33.5	21
Jack ♂	18	51.9	Josie	16	41.2	5
Mona	25	66.0	Jack ♂	18	51.9	29
Pan ♂	16	46.9	Mamo	9½	39.3	1
Pan ♂	16	46.9	Mona	25	66.0	5
Pan ♂	16	46.9	Pati	18	48.6	27
Pati	18	48.6	Bokar ♂	13	47.2	1
			Mature females			
Dita	18	41.6	Fifi	20	37.8	13
Josie	16	41.2	Soda	10½	37.4	13
Lia	14	40.7	Josie	16	41.2	16
May	13	40.0	Dita	18	41.6	13
Mimi	15	48.9	Fifi	20	37.8	21
Mimi	15	48.9	May	13	40.0	13
Nira	12	40.7	Cuba	12	40.5	34
Pati	18	48.6	Dita	18	41.6	6
Soda	10½	37.4	Mamo	9½	39.3	20
Wendy	15	45.0*	Nana	17	41.0*	16
			Mature and immature females			
Lia	14	40.7	Alpha (Im.)	7	39.0	3
Bentia	12	33.5	Bula (Im.)	7½	31.6	4
Mamo	9½	39.3	Lita (Im.)	8	32.8	13
			Immature females			
Alpha	7	39.0	Lita	8	32.8	21
Bimba	8½	33.6	Bula	7½	31.6	22

* Weight with nursing infant.

TABLE 2

Dominance-subordination observations for the mates Mona and Jack

SUBJECTS AND DATE	SEXUAL STATUS*	DOM. OR SUB.	1ST OR 2D	RESPONDED	RIGHT OR PRIVILEGE	REMARKS ABOUT BEHAVIOR
Mona June 4	Max g.s.	D	1	Yes	Right	Came to gate panel
Jack	—	S	2	Yes	Privilege	Responded on wall at side
Mona June 5	Max g.s.	S-D	2	Yes	Rt.—Priv.	Yielded privilege to Jack Reversal of relation
Jack	—	D-S	1	Yes	Right	Came to gate panel
Mona June 6	$-\frac{1}{8}$ g.s.	D	2	Yes	Right	Begging, impatient, militant
Jack	—	S	1	Yes	Privilege	Calm, patient, yielding
Mona June 7	$-\frac{3}{4}$ g.s.	D	1	Yes	Right	Impatient and irritable
Jack	—	S	2	Yes	Privilege	Calm, discreet, yielding
Mona June 8	$-\frac{1}{2}$ g.s.	D-S	1	Yes	Right	Came to gate panel They worked side by side
Jack	—	S-D	2	Yes	Privilege	Came to gate panel
Mona June 9	$-\frac{1}{4}$ g.s.	Equality	1	Yes	Right	Impatient when incorrect Both responded at gate
Jack	—		2	Yes	Right	Calm, fearless, assertive
Mona June 10	P.R.	D-S	1	Yes	Rt.—Priv.	No interference with Jack
Jack	—	S-D	2	Yes	Rt.—Priv.	Calm and assured
Mona June 11	P.R.	S	2	Yes	Right	Calm Reversal of relation
Jack	—	D	1	Yes	Right	Impatient, vocalized
Mona June 12	P.R.	D-S	2	Yes	Right	Impatient Both responded at gate
Jack	—	S-D	1	Yes	Right	Calm and fearless
Mona June 13	P.R.	S-D	2	Yes	Right	Murmurs of protest
Jack	—	D-S	1	Yes	Right	Calm, assured
Mona June 14	P.R.	S-D	2	Yes	Rt.—Priv.	Somewhat impatient
Jack	—	D-S	1	Yes	Right	Calm, assured
Mona June 15	P.R.	S	2	Yes	Privilege	Did not come to gate
Jack	—	D	1	Yes	Right	Calm, in control

* Meaning of symbols for female sexual status: Max g.s. = maximal genital swelling; $-\frac{1}{8}$ g.s. = lessening of genital swelling (detumescence) by $\frac{1}{8}$; P.R. = permanent residual condition of the genito-anal area.

response (1st or 2d), presence or absence of response, whether response was made by right or privilege, and, finally, outstanding features of individual attitude and behavior.

There were two serious limitations of experimentation. In certain instances, it was impracticable to continue the testing of mates throughout a sexual cycle because of the risk of undesired impregnation; and, in others, the requirements of the experiment conflicted with concurrent investigations which we could not afford to sacrifice. Twenty-two pairs of animals were used. In two, only a single dominance-subordination test was made; with the other twenty pairs, the number of observations (see Table 1) ranged from three to thirty-four. These numbers include only observations recorded on the special form which is represented in Table 2. For most of the pairs of subjects a variable number of observations preceded the use of this record form. Whereas the number and variety of pairs were entirely adequate, the number of observations per pair in many cases is undesirably small. Therefore it is excusable to remark, first, that the observer had as background of knowledge for the present undertaking intimate acquaintance with chimpanzee behavior, individual and social; and, second, the serviceable information and insights gained in a study of mating behavior, during which hundreds of controlled matings have been observed. Certainly the observational data of my immediate inquiry would be wholly inadequate as basis for the descriptive statements, generalizations, hypotheses, tentative conclusions, and problem-formulations which appear in this report had I been unfamiliar with the individual subjects and also with outstanding features of primate social behavior and relations. The above are intended as statements of fact, not as defense or apology, for this is merely a preliminary report concerning an inquiry which, however well begun, has as yet supplied definitive answers to few of the questions which have been, or will be, suggested.

RESULTS OF EXPERIMENT

Under the four categories proposed in Table 1 we shall now examine the results of my experiment to discover the characteristics, variations, and relations of dominance-subordination behavior. The abbreviations "d-s" and "s.s." will occasionally be used to designate dominance-subordination and sexual status.

1. *The behavior of mates.* The male Bokar was dominant over Bentia except when she exhibited genital swelling, at which time he granted her privilege even to the extent of working side by side with him and taking his food. When paired with the female Pati during her sexual swelling, he was dominated by her. Unfortunately opportunity lacked to determine whether the d-s relationship would change, as happened with Bokar and Bentia, when these subjects became sexually indifferent to one another.

Jack, paired with Josie, was definitely dominant over her. He yielded privilege to her during genital swelling, but reversal of d-s was not observed. By contrast, the pairing of Jack and Mona exhibited the dominance of the female while in genital swelling, whereas at other times the male controlled the social situation. However, Mona yielded first place to her mate reluctantly and with many vocal and gestural protests. Additional information about the behavior of this pair appears in Table 2.

Pan, a vasectomized male, seemingly in full sexual vigor and known to be extraordinarily self-assertive and aggressive, wholly dominated the female Mamo when

she was in maximal swelling. She presented sexually and was accepted by the male, but, unlike Bentia, she neither assumed nor achieved privilege in connection with the sexual relation and did not dare to come to the gate panel to respond. Possibly had this relatively young and inexperienced female had the courage to assume right or privilege of response, the male might have granted it, for at no time was he markedly aggressive or rough in his behavior toward her.

With the large and reproductively aged female Mona, Pan was consistently dominant, and although he yielded her privilege and was much more considerate and attentive during the genital-swelling phase, he at no time permitted her to assume priority of response, as she frequently was able to do when paired with Jack. This is the more interesting and significant because Jack, although less courageous than Pan, is of much larger frame and at times has weighed 10 kilograms more.

On the other hand, with the naturally dominant and aggressive female Pati, Pan, although at times of sexual indifference dominant over her, ordinarily accorded her priority of response and the right to do as she liked during the genital-swelling phase. The term "right" is here used advisedly, since her behavior clearly expressed right as contrasted with privilege. So marked was the d-s reversal for these mates that Pan on certain days responded slowly and with caution, as if by privilege rather than right.

For the sake of brevity I must now have recourse to general statements in supplementation of these descriptions of the social behavior of pairs and individuals. The following appear as trends or principles of d-s behavior in relation to s.s.

Ordinarily in a pair of mates, the male, if dominant, yields privilege or right to the sexually acceptable female during her period of genital swelling and sexual receptivity. Temporary reversal of the d-s relation may occur. When the genital swelling disappears and the female becomes non-receptive, she is also unacceptable sexually to the male and he again becomes dominant. The female of the pair may use sexual response to achieve privilege. This is exemplified in the behavior of Bentia and Bokar.

If in the pair of mates the female happens to be the naturally dominant individual, she may yield privilege or right to the subordinate male for the period of her genital swelling, and the d-s relation may during that time be reversed.

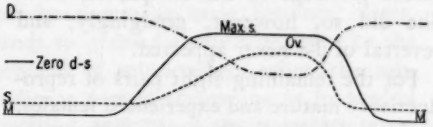

FIG. 2. DIAGRAMMATIC REPRESENTATION OF THE RELATION OF DOMINANCE-SUBORDINATION TO FEMALE SEXUAL STATUS

The solid line (————), beginning and ending with M, menstrual bleeding, indicates the status of genital swelling from the non-tumescent residual condition immediately after and before M to its maximum at Max. s.; Ov, time of ovulation; the broken line (— · — · —) represents the strength of dominance or subordination response of the dominant mate, D; the dotted line (----------) that of the subordinate mate, S, in the different phases of the sexual cycle.

The accompanying diagram, Fig. 2, is an attempt to represent the variations of d-s in their relation to phases of the sexual cycle, as observed in the pair Bokar and Bentia, and, less definitely and completely, in pairs Jack and Josie and Pan and Pati.

2. *The behavior of mature females.* Ten pairs of females, of whom all except Nira had been pregnant or borne young, were observed. Although Wendy and Nana, whose behavior has already been described briefly, belong in this category, they are not comparable with the other pairs because of the presence of nursing

infants. For them the social situation was much more complicated than for the other pairs, since four individuals were concerned in the social responses. It will be recalled that the dominant Wendy yielded priority of response to subordinate Nana when the latter exhibited non-menstrual genital swelling. The change in their social relationship gained expression in other behavioral patterns in addition to those of d-s.

The case of Pati and Dita, as already described, revealed that Pati, a strongly dominant individual, when sexually receptive would occasionally grant masculine privilege to her companion Dita. She did so, however, grudgingly, and reversal of d-s never appeared.

For the remaining eight pairs of reproductively mature and experienced females, variety of behavioral pattern is far more impressive than uniformity. Nevertheless, certain behavioral trends and principles are evident.

Dita and Fifi, spirited, aggressive individuals of long acquaintance, struggled continuously for priority. Although smaller and physically inferior (weights: Fifi, 38 kg.; Dita, 42 kg.), Fifi, by courageous and determined self-assertiveness, was able at times to command first place. Her gain in privilege or control parallels her entrance into the genital-swelling phase. Especially notable is the daily fluctuation of d-s relation in this pair. Neither could confidently assume dominance, for commonly it was challenged by the companion.

May and Dita, as pair, are exceptional in that May, the younger and smaller individual, was dominant. When May entered the genital-swelling phase, Dita became unresponsive and refused to work in my experiment. This is puzzling. It may have appeared as reaction to her companion's sexual condition.

In the pair Josie and Soda, the former was decisively dominant. There is some evidence that slight privilege was accorded Soda while in genital swelling.

Lia and Josie, of whom the smaller, Lia, was consistently dominant, were in identical sexual phases during the period of my experiment, and it consequently was impossible to discover the relation of d-s to s.s. The results, however, indicate that when Lia entered the phase of detumescence she tended to yield privilege increasingly to Josie.

Soda and Mamo grew up together in intimacy of acquaintance. The former was the older; the latter, the heavier. Soda assumed dominance. When Mamo exhibited genital swelling, Soda occasionally took the rôle of male. A description of her behavior is essential. She seated herself behind Mamo in the position sometimes taken by a male, pressed her abdomen against Mamo's genital swelling, and made movements which simulated pelvic thrusts. The rhythm of the thrusts was much slower than is usual in the copulating male. It was not observed that Mamo solicited this attention by her companion, and it was my impression that Soda took the initiative. Certainly Soda took the part of the male perfectly, and Mamo as perfectly coöperated with her. Just before the final trial in my experimental series of June 6th, Mamo presented sexually to Soda and again the latter assumed the male position. In this behavior Mamo responded as subordinate female with privilege, whereas Soda obviously played the part of the gentle and considerate male seeking sexual favor.

Mimi and Fifi represented contrasts, for the former was much the larger and Fifi the more courageous and determined. Mimi naturally assumed right of priority and attempted to dominate her com-

panion, while Fifi persistently, and sometimes with success, disputed this right. Indeed, she never yielded completely to Mimi, and from day to day conflict persisted. Between May 24th and June 15th, the period of observation, several fluctuations and one reversal of d-s relation were noted. The relation of d-s to s.s. was obscured by the fact that the sexual cycles were nearly parallel.

Mimi and May also represented mass (Mimi, 49 kg.; May, 40 kg.) as against courage and self-assertiveness. Unfortunately the sexual cycles were nearly contemporaneous. Mimi assumed dominance and May fought against subordination. Although she never succeeded in gaining first place in the experiment, she continued to fret and complain, seldom risking combat with her larger companion. The d-s relation, although not actually in flux, was constantly jeopardized by May's refusal to accept subordination.

Nira and Cuba differed slightly in size. The former was dominant. The d-s relation varied appreciably in strength with the s.s. of the individuals, but without reversal. On June 14th, with Nira in maximal genital swelling and probably also in oestrus, and Cuba in menstrual phase, the dominance of the former and the subordination of the latter were decidedly weaker than usual. Cuba was markedly more confident and venturesome. Taking the rôle of male she backed up to Nira and rubbed her genitalia against Nira's swelling. This pattern of homosexual behavior differs strikingly from that previously described for Soda and Mamo. Nira at this time was coöperative, gentle, friendly, and entirely passive. Once on this date Cuba came to the gate panel—which she rarely had the courage to do because of the risk of provoking attack by her dominant companion—but evidently feeling unsafe she looked toward Nira inquiringly as she prepared to respond to the boxes.

From the results for these several pairs of mature females it is evident that d-s may remain in flux over a considerable period, varying in strength, direction, or both, with daily incident and accident; that it is influenced in varying degrees by the s.s. of the female companions; and, finally, that the direction of change in d-s relation corresponding to change in the phase of s.s. may not be stated simply and dogmatically, since it apparently varies with pairs and individuals. However, ordinarily the dominant female, as is true of the dominant male between mates, tends to grant d-s privilege, even to the reversal of relationship, when the subordinate female companion is in genital swelling, whereas if she is in this phase of the sexual cycle herself she may encourage or permit her subordinate companion to act as male. Either the dominant or the subordinate female may assume the rôle of male toward the sexually receptive companion.

These facts have been established. The d-s relationship of female companions varies with their sexual status. Homosexual behavior may occur, and at times it may simulate the heterosexual pattern. It is especially worthy of remark, and also of further inquiry, that whereas in many of the other mammals (e.g., cow, sow, guinea pig) when two or more females constitute a social group, the individual in oestrus mounts the companion, in the chimpanzee the female in oestrus instead is mounted or rubbed against by a companion who acts as male.

3. *The behavior of mixed pairs—mature and immature.* It is pertinent to inquire how s.s. is related to d-s patterns in pairs of females only one member of which is mature and capable of exhibiting the several phases of the sexual cycle, and in

which therefore the s.s. influence must be uni-directional. The exhibits are limited to three cases.

Lia and Alpha showed reversal of d-s entirely independently of s.s., for initially Alpha assumed dominance, perhaps because of recency of association with individuals who accepted her as dominant, or, more likely, because of her natural aggressiveness and the fact that Lia was introduced into Alpha's cage. The social scene shortly changed, for Lia asserted herself and in physical combat quickly robbed Alpha of dominance. Protesting vigorously, the latter accepted subordination. Lia was the older as well as the reproductively mature and experienced member of the pair, and she was also slightly heavier, although in appearance she seemed smaller than Alpha.

The case of Bentia and Bula offers points of exceptional interest. Bentia, the mature and experienced individual and the larger, instead of initially asserting herself as naturally dominant, generously allowed Bula to work beside her in the experiment. When Bula in her proper turn took food from an experiment box, Bentia sometimes would beg for it vocally, gesturally, or even by sexual presentation and the rubbing of genitalia. On occasion Bula might respond to such sexual advance in the rôle of male. Although the male position was taken, there were no pelvic thrusts. At the time of these observations Bentia exhibited a small genital swelling. She was not in oestrus. Recalling the previously described relationship of Bentia with the male Bokar, it may be wondered whether her homosexual behavior with Bula was determined by her experience with Bokar, or whether it would have occurred independently of heterosexual experience. Subsequently Bentia became markedly dominant over Bula. This appears to be a clear case of relationship between d-s and s.s.

In the pair Mamo and Lita—the former mature, experienced, and in genital swelling during my period of observation; the latter, a volatile adolescent—reversal of d-s occurred. At first Mamo gave Lita priority, but on the second day of experimentation, and thereafter, she became dominant. The case is important as exhibiting approach to d-s balance between an unusually aggressive, pugnacious, mature female and a rather flighty and timid adolescent female. The privilege which Mamo initially granted Lita may be attributed to the fact that the former was in an advanced stage of tumescence and presumably sexually receptive.

From the observation of these three cases of mixed pairs it may be stated that in the association of mature with immature individuals the older and more experienced female tends to dominate, and also to initiate sexual behavior, in connection with which she may on occasion subordinate herself temporarily to her sexually immature companion.

4. *The behavior of immature females.* Only two pairs find a place in this category: Alpha with Lita and Bimba with Bula. In each pair the heavier member dominated. No one of the four individuals had exhibited a menstrual cycle. Sexual behavior was not observed during my experiment. The d-s relation was definite and relatively constant for each pair. No reversals were observed. This contrasts strikingly with the fluctuations of d-s relation as exhibited by pairs of mature females.

The following observations relative to sex differences in behavior seem important. In the experimental situation the dominant member of a pair is likely to be restless, impatient, irritable, or even violent, while its companion is working. This be-

havior is more often exhibited by female than by male. The latter exhibits better self-control, ordinarily, and gives place to the subordinate companion with better grace.

The behavior of paired females in the experiment depends on several variable factors, of which sexual status is one. The influence of the latter frequently is obscured by events in daily life which influence affective relations. Examples are: disagreement or contest over food, shelter, possessions. Dominance-subordination may change independently of sexual status, in conjunction therewith, or, it appears, primarily because of the sexual receptivity of a female.

So much has been said about the association of might with right, or, in our immediate terminology, of size with dominance, that it would seem inexcusable to neglect the evidences in this experiment. Does either assure chimpanzee (or man) of the other?

The observational data of weight and dominance, upon which the following statements are based, may be found in Table 1. Among 22 pairs of subjects the heavier member was dominant in 17, the lighter in 5. In the 7 pairings of mates, the male was dominant in 5 cases, the heavier individual also in 5; and in the 15 pairings of females, the heavier individual was dominant in 12.

It is granted without argument that weight is an inadequate measure of either actual or apparent bodily size. Possibly the more dominant a chimpanzee feels and acts, the larger it looks to its companions! The weight averages for the group are misleading because of the small number of cases and the inclusion of an exceptionally heavy female in each group. With this interpretative suggestion and warning, the pertinent statistics are presented.

Average weight in kilograms for pairs (17) in which the heavier member was dominant: for the dominant individual, 44.8 (A.D. 5.7); for the subordinate individual, 38.6 (A.D. 4.0). If from this group the exceptionally large individual Mona and her mate Jack be omitted, the averages become: dominant individual, 43.5 (A.D. 4.8); subordinate individual, 37.8 (A.D. 3.4).

Average weight for pairs (5) in which the lighter member was dominant: for the dominant individual, 42.4 (A.D. 3.6); for the subordinate individual, 47.3 (A.D. 8.0). Or, omitting the pair in which Mona appeared (Pan-Mona), the averages become: dominant, 41.3 (A.D. 2.9); subordinate, 42.7 (A.D. 3.0).

Physique, as inclusive of weight, apparent and actual size, strength, vigor, and endurance, obviously is positively correlated with dominance, but so also is psychobiological constitution, as determined by heredity and experience and including intellectual as well as affective traits. I have given physique first place because of the statistical balance in its favor, but it is my impression, from acquaintance with my subjects, that their psychobiological traits are more important in shaping their social rôle and relations than are traits of physique. Courage, the assurance of manner characteristic of self-confidence, persistence, and the unquestioning expectation of dominance expressed in bodily posture and attitude, are as obviously determiners of patterns of social relation in chimpanzee as in man.

The observational data which have been presented should not be accepted as adequate basis for definite descriptions of patterns of social relation and change. From them, principles are deducible, but in many instances they cannot be convincingly grounded on fact and must stand as suggestions to be used in problem formulation. Several pairs of subjects supplied

clear-cut, readily interpretable results, but the remainder, because of the several limitations of the inquiry, exhibited instead varieties of d-s pattern, factors affecting or correlated with such patterns, and evidence of the importance of sexual status, which are difficult to evaluate. The results make clear the desirability of observing expressions of social relation in several pairs of individuals, under reasonably constant or comparable conditions, through a number of sexual cycles.

SEX, DOMINANCE, AND PERSONALITY

The chimpanzee is an open book, from which, according to our technical preparedness, patience, skills, and insights, we may read the characteristics, relations, and functional significance of sexual and reproductive behavior. For in it the social taboos, personal inhibitions, superstitions, modesty, shyness, and self-consciousness which render the objective and trustworthy study of human sexual behavior extremely difficult or impossible, are relatively inconspicuous. Relatively I say, because in some degree most of them appear as barriers even in the study of the anthropoid ape. Nevertheless, chimpanzees are incomparably more favorable than are we for the investigation of many psychobiological problems of sex and reproduction.

Obviously, correct and adequate descriptions of the principal patterns and relationships of sexual behavior are essential in connection with inquiry into the rôle of sex in social life. For ourselves, knowledge, although extensive, is difficult to evaluate, whereas for the chimpanzee useful descriptions either are available or may be obtained without great difficulty. Therefore, I submit that such observational items as appear in this report, and in related studies of the psychobiology of sex in the anthropoid apes, should have exceptional value for those who concern themselves with problems of social behavior, and, especially at this juncture, for those psychopathologists who are intent on appraising, perfecting, and using psychoanalytical method of observation and interpretation. Currently available knowledge of the sexual behavior of chimpanzees, and in particular that which I have gained in the present investigation and from a study of the patterns and characteristics of mating behavior, constitutes the factual basis for what follows and stands as my sole excuse for writing these paragraphs on anthropoid versus human personality.

In the chimpanzee, personality stands revealed less definitely than in man, but nevertheless very clearly, as the unit of social organization. I have chosen the term personality as preferable to self and individuality and as inclusive of constituents of the id, ego, and superego. It has the psychological and sociological implications which I wish to convey. I use the term to designate the product of the integration of all the psychobiological traits and capacities of the organism. In chimpanzee, as in man, it appears as a functional whole, whose importance for the understanding of social phenomena is incomparably greater than that attaching to the differentia of species, sex, and either structural or functional individuality. In the smoothly functioning, normal, socially effective personality, the basic organic needs or hungers of the natural self are integrated with the hereditary and acquired characteristics of the conscious self. The necessary integrative processes include at least the following as significant elements: forms of inhibition and reënforcement, supplementation, subordination, substitution, and coördination. Personality imbalance due to under- or over-emphasis of essential constituents, as

exemplified in timidity, gluttony, avariciousness, sexual frigidity, or lasciviousness, tends in ape and man to be prejudicial to or destructive of social values.

It is desirable to discover the rôle and relative importance of sexual phenomena in the social life of the chimpanzee. Do they constitute the core or nucleus of anthropoid personality, as Freudian psychopathologists believe to be the case in man, or are they instead merely one among many highly important factor-assemblages in a very complex functional whole? What, in this connection, is indicated by our observations?

The answer may not be stated dogmatically, for evidently we know only in part. I should put the matter thus. Several biological requirements—needs, appetites, desires, interests—in addition to those of sex are evidenced by chimpanzee behavior. Among them are such needs as the nutritive, protective, defensive, developmental (exercise, play), social (companionship, mutual aid), exploratory, inventive, constructive (Yerkes, 1933). These are examples from a long list. There are times when sexual interest and activity overshadow all others in the life of the ape, but frequently, and for long intervals, they remain inconspicuous or in abeyance. At such times the organism may be described as sexually neutral or indifferent. The personality is the while controlled or dominated by other hungers. If one follows the daily life of the ape, it is discovered that non-sexual activities occupy all but a very small fraction of the time. There is no adequate reason to assume that the rôle of sexual function outweighs either the nutritive or the non-sexually social. The fact should here be faced that human interest has tended unduly to magnify sexual behavior in other animals as well as in man himself. This may be attributable in considerable measure to the psychoanalyst's preoccupation with clinical cases.

Indicated also by my observations, and with clarity and force, is the fact that the rôle of sex differs markedly in male and female, and that chimpanzee personality, whatever may prove to be true of our own, can be adequately described only in terms of masculinity and femininity. The fact is exemplified by the foregoing exhibits of the characteristics of dominance-subordination behavior in their relations to sexual status and activity. Although otherwise the male and female personalities may be very similar, certainly in the nature and expressions of sexual interest and their part in the life of individual and species the sexes are as different as give and take, act or wait, command or obey, right and privilege. In making this statement I am not overlooking the fact that either sex in chimpanzee, as in man, may on occasion be dominant. The fact that in size and strength the adult male ape usually is superior to the adult female determines, or at least favors, a type of social organization—the patriarchal family—in which the female tends to be subordinated to the male even though by nature she may be a dominant individual.

Lest the reader too readily assume that knowledge of the social-sexual life of the chimpanzee can have no values for man other than the satisfaction of his curiosity, since ape and man are so utterly dissimilar, I invite attention to significant likenesses. Notable are the facts relative to characteristics of the structurally determined (hereditary) patterns of sex behavior, the rôle of experience in the perfecting of these basic patterns, the occurrence of affective social attachments and of such varieties of maladjustment as masturbation, rape, and prostitution. There is grave disparity between fact and prevalent opinion.

From a widely read and opinion-molding book by the eminent anthropologist Malinowski, I quote relative to the presumptively sharp contrasts between the sexual life of anthropoid ape and of man:

> Let us compare the chain of linked instinctive responses which in animals constitute courtship, marriage and family with the corresponding human institutions. Let us, point after point, go over each link in the love-making and family life of anthropoid apes and ascertain what in human beings corresponds to each.
>
> Among apes the courtship begins with a change in the female organism, determined by physiological factors and automatically releasing the sexual response in the male. The male then proceeds to court according to the selective type of wooing which prevails in a given species. In this all the individuals who are within the range of influence take part, because they are irresistibly attracted by the condition of the female. Rut provides opportunities for display on the part of the males and for selection on the part of the female. All the factors which define animal behaviour at this stage are common to all individuals of the species. They work with such uniformity that for each animal species one set of data and only one has to be given by the zoologist, while, on the other hand, they vary considerably from one species to another, so that for each species a new description is necessary. But within the species the variations, whether individual or otherwise, are so small and irrelevant that the zoologist ignores them and is fully justified in doing so.
>
> Could an anthropologist provide such a formula for the mechanism of courtship and mating in the human species? Obviously not. It is sufficient to open any book referring to the sexual life of humanity, whether it be the classical works of Havelock Ellis, Westermarck, and Frazer or the excellent descriptions in Crawley's *Mystic Rose*, to find that there are innumerable forms of courtship and marriage, that seasons of love-making are different, that types of wooing and winning vary with each culture. To the zoologist the species is the unit, to the anthropologist the unit is the culture. In other words, the zoologist deals with specific instinctive behaviour, the anthropologist with a culturally fashioned habit-response. (1927, pp. 193–194)

At the time of writing, Malinowski's statements relative to the anthropoid apes transcended trustworthy information; today they are contradicted by it. I shall criticize the quoted statements in the light of knowledge of chimpanzee behavior, omitting mention of the other great apes—gorilla and orang-outan—because they are relatively less well known psychobiologically.

From recorded observations of chimpanzee sexual behavior the following facts and principles appear. The courtship and mating activities and behavioral patterns of individual, pair, or group differ so markedly that they may be used for identificational purposes. In other words, patterns are numerous and diverse; variability is high. True I have no measure of diversity of sexual behavior or of its variability in individual or pair for chimpanzee or any other anthropoid ape, and I doubt that Malinowski has for man. So without apology I oppose my observations to his comparative statements and assert that the contradiction is complete. Further, I hazard the prophecy that when measures of diversity and variability for the sexual behavior of chimpanzee and man are available, the figures for the former will be greater than expected, those for the latter relatively less, and that both sets of measurements will be greater than comparable data for the other mammals. In the last paragraph quoted from Malinowski, it appears that the author assumes the existence of species in anthropoid apes, with diversity of sexual behavior, and accepts the genus *Homo* as a single species. Again observation fails to sustain his contention, for certainly what are recognized as species differences among chimpanzees are neither greater nor more significant functionally than are those exhibited by the so-called races of man.

It is commonly assumed by sociologists, as Miller (1928) has pointed out with disapproval, that in his sexual psychology man differs radically from all other ani-

mals. Our present knowledge would not justify challenge of the assumption were it understood that as between man and anthropoid ape the difference is in degree and proportions, not in kind.

Whereas the sexual life of chimpanzee manifestly is on the instinctive level, and relatively little influenced by such functions as self-consciousness, introspection, representative processes in the shape of memories and imaginings, that of man, although also as natural function structurally determined, is constantly and powerfully influenced by consciousness. The chimpanzee exhibits sexual activity when affected by natural and specific stimuli or stimulus situations, although it is not strictly and narrowly limited to such behavior. While, by contrast, man, under the influence of representational processes, tends constantly to supplement natural stimuli by the creation of imaginary sexual situations. This is the conspicuously important point of contrast between ape and man. In the one, representative process is relatively simple and infrequent, as indicated by the outcome of experimental inquiries; in the other, it is very prevalent. Largely because of this psychobiological difference, mating in chimpanzee tends to be restricted to that period of the sexual cycle near the time of ovulation, when copulatory activity is functionally appropriate, whereas man mates almost irrespective of biological fitness and value for reproduction and often independently also of the biological need, desire, or preference of the female. It is revealed, to be sure, that some men (generic) are nearly animal, some apes nearly human, for instinct survives in man and culture has dawned in chimpanzee. Id and ego-superego functions are reversed in relative importance in these two types of primate, but in neither of them are the instinctive or the conscious factors lacking.

On a factual basis I have attempted to support the proposition that similarities of ape and man as social organisms are not less conspicuous and significant than are differences. I might add as opinion that it seems stupid of us to neglect or to exaggerate either. Such being the case, it is fitting to suggest that dominance as behavioral trait may be quite as important in our own lives as in that of the chimpanzee. It may not be disputed that in the latter it is an all-pervasive principle of social relationship and of organization, inasmuch as each group tends to be determined and regulated by it.

What I shall say concerning the possible significance of dominance in human life may best be stated hypothetically and with extreme brevity and caution. If in man dominance as personality trait is highly correlated positively with leadership, as it evidently is in chimpanzee; if it is a condition of or markedly favorable to individual initiative, inquiringness, inventiveness, and creativeness; and if, further, it should prove to be reliably measurable during childhood, it may very well come to possess conspicuous values as indicator of vocational aptitudes and social usefulness and therefore also as basis for differential educational treatment and occupational choice. Even marital advice might be affected by it, for congeniality or social fitness may depend appreciably upon similarity or the reverse in dominance as personality trait of mates or companions.

Another possibility suggests itself, which affects primarily the social rôle and status of woman. Assuming that dominance is hereditary and that in inheritance it is independent of sex, men and women might be expected to become creative leaders with approximately equal

frequency. According to statistics, this is not the case in our civilization. It is a natural inference from available data (Terman and Miles, 1936) that our culture is favorable to the development of dominance and to its behavioral expressions in the male and relatively unfavorable to this same development and expression in the female.

I have attempted to suggest problems as well as to state facts. The path to discovery is open and inviting. There is no obvious reason why the informational gaps which have compelled me to substitute hypothetical for factual statements should not speedily be filled. Both ape and man should serve invaluably, according to their peculiarities and availabilities, as experimental subjects.

SUMMARY

When two or more chimpanzees are associated, dominance appears as principle of social relation and a hierarchy is constituted by the dominance order, for every individual tends to be more or less dominant or subordinate to every other.

Dominance implies priority of response; the right or privilege to satisfy all individual needs or desires irrespective of those of companions; and, possibly also, the obligation to exhibit leadership and initiative in the interest of social welfare.

Every individual appears to be by nature either dominant or subordinate. Either sex may be dominant over the other. The larger, older, and more experienced individual ordinarily has advantage.

The dominance-subordination patterns of response are dependent primarily on traits of physique (size, strength, endurance) and of psychobiological constitution (temper, courage, assurance, persistence).

In a simple food-response experiment, the dominance-subordination relation of twenty-two pairs of adult and adolescent chimpanzees was tested to discover the significance of sexual status. The importance of sexual condition was established.

Dominance-subordination is not a constant relation. It fluctuates or even changes in sign with the sexual status of the female and with such events of daily life as disagreements, contests, or quarrels over food, shelter, possessions, social privilege.

The male if dominant grants privilege to, or is dominated by, the female when she is in oestrus, whereas if subordinate to her he may achieve privilege to the extent of priority of response when she is sexually receptive.

Pairs of mature females exhibit dominance-subordination relationship as do mates. Ordinarily the naturally dominant individual, if in oestrus, grants privilege to her subordinate companion, whereas the subordinate, in oestrus, may achieve privilege and act as if temporarily in control.

In the experiment reported, the dominant member of a pair frequently was restless, impatient, or ill-tempered while waiting for its subordinate companion to take its turn. This emotional response was more common in females than in males. The male is more generous and good-tempered toward a female companion than is another female.

Associated female chimpanzees may exhibit homosexual behavior which closely simulates the heterosexual. But whereas in many other mammals the female in oestrus commonly mounts a companion of like sex, the chimpanzee in these circumstances is mounted.

The mating behavior of chimpanzees may be initiated by either sex, and its form and consummation seem to depend in many cases as much on the one sex

as on the other. The prevalent statement that sexual initiative and control rest with the male is erroneous.

Sexual perversions are exhibited. Examples are: masturbation and hypersexuality by either sex; rape by the male; frigidity and prostitution by the female. The terms are used objectively to designate patterns of behavior and have no reference to purpose or intent.

Chimpanzee sexual life, although greatly modified by experience, is primarily instinctive; that of man, conspicuously imaginative. But clearly neither is nor could be exclusively determined by structure or by experience.

The superior size and strength of the male enhance the opportunity of this sex for the development and exercise of initiative and constructivity.

In turn, the prevalent and characteristic cultural pattern of chimpanzee life (for instance, the patriarchal family group), as presumably has been true also of man, tends to favor the development of capacity for dominance, leadership, originality, and creativeness in the male, and, correspondingly, of subordination, imitativeness, and conventionality in the female.

Dominance-subordination, as traits of behavior, may turn out to be of far-reaching theoretical and practical significance for social sciences, education, and medicine. The issue rests with discovery of the relation of the traits to sexual processes, leadership, the spirit of inquiry, and constructivity, for any readily measurable trait which is highly correlated positively with the above should have great diagnostic value.

The chimpanzee is peculiarly valuable for the study of many problems of sex and reproduction, because readily observable changes in the volume, tension, and color of the external genitalia, occurring in the course of the typical five-week sexual cycle, make it possible to date menstruation, oestrus, and ovulation, and also because the social and individual inhibitions, self-consciousness, modesty, and shame, which are barriers in the study of man, are virtually absent in the ape.

It does not appear from the results of this inquiry that the activity of chimpanzee is monopolized by sexual interest. Instead, the sexual appears as one among several biologically essential interests and types of activity.

Are dominance-subordination, as personality traits, positively correlated with the congeniality or compatibility of mates and companions? From the inadequate data at hand, it would appear that opposites in dominance-subordination are better suited to one another than are likes. Has this relationship predictive value in connection with the grouping of chimpanzees, human marriage, or other types of social relationship among primates?

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THE PROBLEM OF CYCLOMORPHOSIS IN DAPHNIA

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THE phenomenon of cyclomorphosis among plankton organisms is particularly well exemplified in fresh-water Cladocera, especially in the group of *Daphnia cucullata* and *D. longispina*. Some changes of form may occur in ontogeny, with age, reproductive condition, or environmental modification; but the cycle of forms is best shown in a sequence of generations, which, following one another at intervals of weeks, may be marked by progressive modifications until the whole population is notably different in appearance from a recently ancestral one. Later the changes occur in reverse order and a complete cycle is made (Fig. 1).

SEASONAL VARIATION IN FORM OF HEAD

Summer generations of Daphnia may be so different from winter generations that, before the nature of the phenomenon was made known by Sars (1890) (Fig. 2), Zacharias (1893), and, more particularly, Wesenberg-Lund (1900), the Daphnias of one season were assigned not only to different species but sometimes even to different genera. With Daphnias the most conspicuous change is in the head, which may be extended to make a great helmet-like feature, turned upward or downward, or directed straight forward, with other differences characteristic for the several races. The forward extension of the head may, in extreme cases, be almost as long as the whole of the remainder of the body, so that the eye, which was at the front in winter, is near the middle of the body in summer (Fig. 1). Other changes of form occur, but in the following pages we will, for simplicity, restrict attention to form of head, as manifested in helmet development, and, for brevity, speak of round-head Daphnia (the winter form) and helmeted or pointed-head Daphnia (the summer form).

The changes of form are not simple functions of external conditions or of any inherent cycle, but rather of a combination of internal and external conditions in a way that becomes exceedingly baffling the more we know about it. The environmental conditions involved are the subject of much dispute. The internal conditions, too, are quite unclarified, so that there is discussion of such possible influences as *Präinduction* and position in the "reproductive cycle," or *generation number* (both to be discussed below), with resultant states of *lability*, or degrees of responsiveness.

Heredity, of course, plays its part, but the extent to which heredity governs the particular forms displayed in surprising diversity by the several populations of neighboring waters is not positively known, and there is discussion as to whether heredity may not be actually modifiable by subjection of the race to new environmental conditions for a considerable number of generations. Woltereck (1934, and earlier papers) has adduced

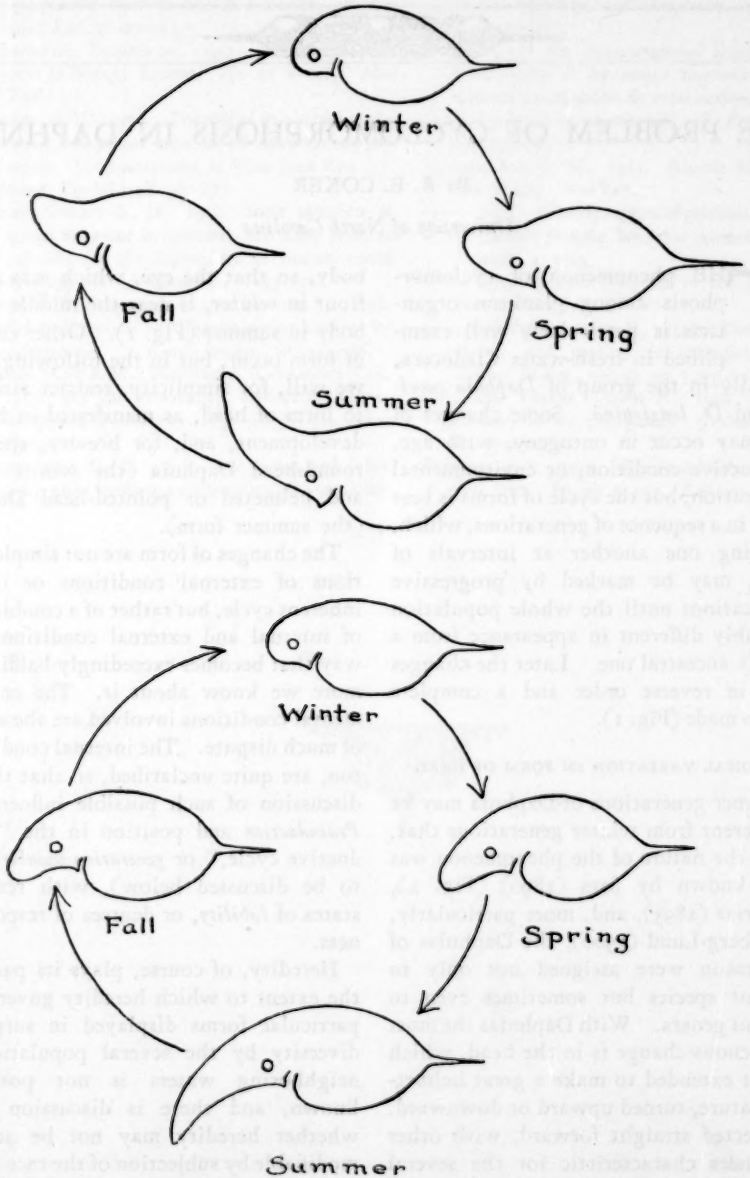

FIG. 1. DIAGRAMMATIC REPRESENTATIONS OF TWO CYCLES, ALIKE IN THE GENERAL COURSE OF EVENTS, AND WITH IDENTICAL WINTER FORMS, BUT CONTRASTING SUMMER FORMS
The cycle need not be quite so simple and regular

evidence that this is the case; he introduced a race of *D. cucullata* from Denmark into a lake in Italy uninhabited by the species and found after a good many generations a changed form which persisted through several generations reared under experimental conditions; the new form was lost by reversion under conditions of *Gegeninduktion*—exposure during several generations to opposing influences. The genetic complex had in his opinion been actually modified during a long period of parthenogenetic reproduction and the modification had persisted for a time, both in the wild and under experimental conditions, but, under the artificial conditions of the laboratory, counter genetic changes were induced in course of a few generations. It would be desirable for conclusions of such significance to genetics and evolution to be checked under conditions of strict control. To many the conclusions stated would seem contrary to the probabilities, but even the well-established facts of cyclomorphosis challenge the probabilities.

The several populations in neighboring bodies of water may undergo synchronous but dissimilar changes. Two lakes in close proximity have Daphnias that are apparently identical in winter but very different in summer; one distinguishes them as subspecies, varieties or races, according to one's taxonomic judgment or taste. When compared in January, the two Daphnias, although quite indistinguishable morphologically, must be assigned to different varieties because their great-grandchildren will be readily distinguishable. The capacity to form helmets of some particular kind is present but latent during a considerable part of the year, so that the genetic possibilities of the race are realized only at certain seasons. On the other hand, with round-headed Daphnias in extreme northern lakes, where the conditions for cyclomorphosis do not occur, the latency is perennial; apparently there can be no identification to variety or subspecies, and the population must be left in the general residium of the species. What would happen with such Daphnias if one changed the summer conditions by supplying warmth remains to be determined.

Now, cyclomorphosis, with its diversity of summer helmets in different waters, would present a complex enough problem if we had to do in all cases with a winter form and a consistently contrasting summer form. In most cases, indeed, the newborn in late spring have helmets in extreme development and there is little

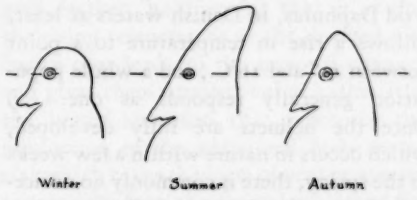

FIG. 2. ILLUSTRATING A VERY MODERATE CYCLOMORPHOSIS OF HYALODAPHNIA CRISTATA (NOW DAPHNIA CUCULLATA G. O. SARS, SUBSPECIES CRISTATA) After Zacharias (1894)

change in ontogeny, but in certain waters, or in certain years perhaps, the cyclomorphic sequence presents its variations. Wesenberg-Lund describes a race in which the young at all seasons are born with round heads while the mature animals show a marked elongation of the head in summer. In another water in Denmark both round and pointed heads occur in winter but the points are high and sharp only in summer. Again he compares two races of *cucullata* from waters less than half a kilometer apart, a lake and a pond with insignificant difference in temperature: in the lake a marked cyclomorphosis extends through the summer; in the pond a dwarf but heavy race begins a cyclo-

morphosis in June and then, in July, the crest diminishes until typical round heads appear in August. In our University Lake near Chapel Hill, N. C., where there are only round heads in winter and sometimes only pointed heads in late spring, we have found some round heads along with the pointed heads in late spring; and, in fall, we have found all round heads one year and a mixed population of round and pointed heads another year. These are merely examples of the diversity of manifestation of cyclomorphosis.

It is well to state here in summary form what seem, from the literature, to be the most clearly established facts regarding the occurrence of cyclomorphosis of Cladocera in nature: (1) A change of form of wild Daphnias, in Danish waters at least, follows a rise in temperature to a point between 12° and 16°C., and a whole population generally responds as one. (2) Once the helmets are fully developed, which occurs in nature within a few weeks in the spring, there is commonly no noticeable further development in later generations with continually rising temperatures; consequently there is only partial correlation between length of helmet and height of temperature. (3) There may occur in autumn a gradual reversion from summer to winter form, or there may be a virtual disappearance of Daphnia in summer (after formation of ephippial eggs?) and a resurgence of exephippial round heads in fall. (4) Helmets once formed are commonly held (in nature) throughout life, although some modification may occur from molt to molt. (5) Increasing richness of food supply is likely to be synchronous in spring with development of helmets, but correlation of length of helmet and abundance of provender is at best only partial and poorly established. (6) The correlation between length of helmets and either temperature or nourishment fails badly when different waters are compared, but what is true of *length* of helmet is not true as regards *time* of first appearance of helmets. (7) There is some correlation, a rough one at least, between size of water (ponds, small lakes, large lakes), and degree of helmet development, whatever that may signify (Gruber, 1923, for *Scapholeberis mucronata*). (8) There occur minor exceptions to the regularity of the sequence of change (see Wesenberg-Lund, 1926; Coker, 1938). (9) Comparing different bodies of water, either remote or neighboring, the general form of the helmet is characteristic for the several populations, although degree of development is variable with time and individual. (Facts regarding the hereditary nature of the multitude of helmet forms are of course derivable only from experiments.)

SOME THEORIES REGARDING HELMETS

It is our habit, and one that might be called almost inveterate, to assume for any phenomenon of organic life that it is adaptive, meaning that it has something to do with the welfare of the organism or that it has survival value. This seems on the face of it to be true of most, but probably not of all, structural or behavioral characters. It is not unnatural, then, that the cyclomorphosis peculiar to plankton organisms should have been the subject of study and of speculation with respect to its utility in the special conditions of life of the plankton. Hence arose the "buoyancy theory" of Wesenberg-Lund (1900): helmets, spines and other processes or protuberances offer resistance to sinking and are therefore more needed in summer, when the water is warmer and lighter than in winter. (The term "flotation processes" is in common use for the bodily extensions in the form of helmets, mucros, spines, setae, etc., but, in view of the ambiguity of the word *process* in Biol-

ogy, I shall, in this paper, employ the less euphonious term "Protuberance." The immediate question is whether the flotation "processes" are concerned in the "process" of floating!) The view of Wesenberg-Lund was soon modified by the "plankton theory" of W. Ostwald (1902, 1904), who followed Wesenberg-Lund in general, but, after a critical study of the seasonal variation of physical conditions of life of the plankton, found the significant variable, as regards velocity of sinking, to be viscosity rather than density. Since viscosity was a function of temperature, he proposed to substitute "temperature polymorphism" for the old term "seasonal polymorphism." The correction as to viscosity in lieu of density, having been accepted by the former author, the Wesenberg-Lund - Ostwald flotation theory won wide acclaim for a time after 1904. It was but a few years, however, before Woltereck (1909, etc.) approached the problem of utility from a different angle and changed, as it were, a problem of statics into one of dynamics.

For Woltereck's masterly analysis of the mechanism of locomotion in several cladoceran species, the interested reader is referred to his paper of 1913. It is too elaborate for adequate summary in a brief space, but the features of his views of special interest in this connection are: (1) that the normal position of Daphnia in the water is not such as to make the protuberances effective as organs of flotation; (2) that the Cladocera are active and not passive bodies; and (3) that the protuberances dealt with in studies of cyclomorphosis are not for flotation but are directive and stabilizing surfaces, like rudder and keels of a ship, which serve their functions in guiding the active movement of the animal rather than in keeping it afloat; they aid in maintaining equilibrium and enable the animal to swim in horizontal paths and thus keep within a relatively thin stratum of water; in brief, it is because of these that the cladoceran does not move in circles or continually turn somersaults forward or backward. The point of application of the propulsive force in locomotion (the base of attachment of the antenna) does not coincide with the center of gravity of the body, but is in advance of it; furthermore, the direction of the effective force of the stroke of the antenna is not parallel to the long axis of the body, but is at an angle thereto and would, therefore, tend to swing the animal about its axis, clockwise or counter-clockwise, according to species, were there no control in the nature of a rudder mechanism. He goes further, holding (4) that it is not the rising temperature or the lowered viscosity that leads to the seasonal changes and gives them survival value; rather it is the better nutrition that promotes the production of the additional body material which takes the form of new or greater outgrowths from the general outline of the body. The outgrowths, having directional value, tend to keep the animals in the stratum of the better food supply that produces the outgrowths. (One may reflect, however, that rudders and keels function only by virtue of the density and viscosity of the medium in which they are used and that viscosity of the water in which the Daphnia lives may be only half as great in summer as in winter. "Eddy viscosity" is also a complicating factor in the problem.)

Woltereck holds, too, rather definitely, that the special structures arise in response to need and he sees some sort of direct action of the environment as more effective than individual modifications, which are non-inheritable; than mutations, which occur, but with insignificant effect on cyclomorphosis or on the origin of subspecies; or than *Dauermodifikation* (per-

sistent modification) lasting through only four or five generations and to be discounted as the consequence, originally, of some physiological injury. Most significant is what he conceives as *Differentiation*, referring to collective hereditary alterations that appear in whole populations in response to definite stimuli and are retained in heredity for many generations or until some other collective hereditary alteration serves to undo them. As possibly effective environmental stimuli to induce collective differentiation he depreciates temperature, viscosity and other physical conditions and attaches prime importance generally to nutrition or to something which he rather vaguely terms the *Besonderheit* of the environment (1934).

It has already been intimated that we could not in a brief space expect to do justice to Woltereck's views expressed in a considerable number of long papers over a period of nearly thirty years. Two other features of his theory should, however, be alluded to. Nutrition plus genes is not enough; the capacity of an animal to utilize nutritive substances for the development of extensions of the body depends in great measure upon its place in the reproductive cycle (*generation number*): individuals of the sixth exephippial generation have far greater capacity than those of the second. This is linked with Woltereck's acceptance of the concept of the *reproductive cycles*, first conceived by Weismann, with the corollary concept of "increasing sexuality," a need, progressing from generation to generation, for the change from parthenogenetic to "sexual" reproduction. So much of the experimental evidence of Grosvenor and Smith, Banta and co-workers, Berg and others now relates the changes in mode of reproduction to controllable environmental conditions that the burden of proof of the existence of such a cycle seems clearly to rest upon those who speak of increasing or decreasing "sexuality" as occurring in cyclic fashion, and who relate cyclomorphic capacity to sexuality in that sense. It is possibly in line with this view that newborn from resting (fertilized) eggs are generally, if not invariably, round heads, as well as females, but some evidence to be adduced later seems not to fit at all into a scheme of graded lability, and there are so many differences between parthenogenetic eggs and resting (ephippial) eggs that the exephippial generation may well be exempt from some of the rules governing any later generation.

Woltereck has also introduced the conception of Präinduction for variations which occur as a result of influences exerted on the *germ cells of the developing embryo* in the brood pouch of the mother. Further reference to this is made in connection with the presentation of the results of experiments.

COMMENT ON THE THEORIES

Although our first concern is with the conditions of origin of the helmet, etc., in the individual Daphnia *in vitro* and with the conditions of seasonal origin of helmets in whole populations in the wild, some examination of views concerning the mechanical significance of the structure is, nevertheless, necessary because the question of utility is more or less inevitably involved in consideration of evolutionary origins. Obviously Woltereck's theory involves several practical assumptions: (1) That the best food supply occurs in a relatively narrow stratum in the lakes where cyclomorphosis manifests itself; (2) that the Daphnias when in the expanded form keep to a relatively narrow stratum (for which Woltereck adduces much evidence); (3) that the stratum occupied by the helmeted Daphnia is the stratum at which the food supply is richest (which Wesen-

berg-Lund, with a wealth of field observational data, does not concede); (4) that development of helmets and reduction of helmets are correlated with increasing and declining food supplies (which is the subject of radical differences of opinion, with much uncertainty as to which side of the balance holds the preponderant weight of evidence); (5) that either the unhelmeted Daphnias of winter do swim in circles or that, with the lower metabolic rate of winter, a weaker antennal stroke has less effect in shifting the direction of advance and, therefore, demands less compensative rudder development; (the latter of these alternative assumptions seems plausible, but experimental studies of the locomotion of round-head Daphnias in warm water and of helmeted Daphnias in cold water would be desirable). Obviously, too, Woltereck's view of the causative influence of nutrition offers no explanation for the fact that, although cyclomorphosis appears in lakes where there is relative poverty of food, it often is not displayed by Daphnia, of the same species and of seeming identity in the rounded form, in ponds of apparently the richest nutritive conditions. Similarly, it might be asked with reference to the Wesenberg-Lund-Ostwald theory, and some supporters of the Woltereck view have asked the question: Why do the protuberances not develop in warm shallow ponds as much as they do in cool (but not extremely cold) lakes? The strict adaptationist might well answer either question by saying: That the need for cyclomorphosis does not exist in shallow ponds, however warm and rich in food they may be, for lack of the stratification called for by Woltereck's hypothesis, or for lack of the depth called for by the Wesenberg-Lund-Ostwald hypothesis; that the evolutionary history of the pond race has been different from that of the lake race one hundred yards distant, because of the different environmental conditions—in the one case there was no necessity to mother the invention of cyclomorphosis, in the other case there was.

Without accepting an adaptational explanation for all structures and features of animals, it may yet be regarded as conceivable and perhaps probable that the cyclomorphic specialties of plankton organisms, both plants and animals, do have in summer positively utilitarian value, *both* as flotation protuberances in the Wesenberg-Lung-Ostwald sense and as directive surfaces in the Woltereck sense. We seem, however, to need additional observations to answer certain specific questions. Among such questions are these: (1) Are unhelmeted Daphnias in warm, shallow ponds unable to keep afloat; or, (2) Do they in such waters derive from a relatively rich food supply the greater energy required to keep afloat without helmets? (3) Do Daphnias in such ponds lack ability to move in definite planes; or, (4) Do they, for lack of proper food, expend *less* energy in ponds than in lakes, and so have a reduced tendency to steer away from a direct course and correspondingly less need of keels or rudders? Of course such questions are difficult to attack, but, without more facts, generalizations as to the adaptive nature of the helmets and other protuberances remain presumptive. One question underlies all of those just asked: Are the nutritional conditions in ponds better than in lakes, or not? An experimental study might well start from the still more basic question: What specifically are the nutritive conditions necessary to keep a round-head Daphnia, as contrasted with a helmeted one, in horizontal paths?

Although the discussion of the adaptive nature of the cyclomorphosis of Daphnia includes much that is speculative or at least highly theoretical, the volume of

literature that has developed has brought to light a considerable body of observational evidence which forms an essential part of the background of knowledge and understanding of the reactions that occur in nature and in the laboratory and which are necessary to an ultimate understanding of the phenomena from the points of view of physiology, heredity, and evolution. Nevertheless, there has not as yet been carried out for cyclomorphosis anything like the precise experimental work through which Grosvenor and Smith, Banta and Brown, Berg and others, have so clarified, at least, the problems of sexual and parthenogenetic reproduction in Cladocera. The approach most needed now is through properly controlled experiments to determine the particular stimulus or stimuli to which the animal responds in making the changes of form.

What we have tried to do so far has been: (1) to offer a restatement of the problem, which it has seemed to need, at least in some of its phases, with emphasis on its complexity; (2) to point to the need for more precise experimentation. What we attempt in the following pages is: (1) to summarize the results of our own preliminary experiments dealing with one environmental influence and making, we hope, some contribution to clarification; and (2) to comment on the several angles of interest presented by the problem of cyclomorphosis in Cladocera.

OBSERVATIONS AND EXPERIMENTS

Cyclomorphosis in wild Daphnia

The observations upon Daphnia born and bred in nature were made at irregular intervals during a period of several years (1933–1937) in the recently formed University Lake at Chapel Hill, N. C. In Fig. 3 we give a diagram showing the methods used in measuring Daphnia. There has not yet been opportunity to gather all the data required for a detailed record of the cycle. The story, so far as we have it, may be briefly outlined.

In January, every year, all Daphnias of the species *longispina* have round heads. In late March or early April round and pointed heads occur in approximately equal proportions, and the distance from center of eye to apex of head relative to the distance from center of eye to base of caudal spine (Fig. 3; Y/X) is nearly 50 per cent greater in the latter (0.144) than in the former (0.10). By early May, 1934, only pointed heads were found and the distance from eye to apex was then relatively twice as great ($Y/X = 0.20$) as in January (0.10). No notable change in proportion occurs during May and June.

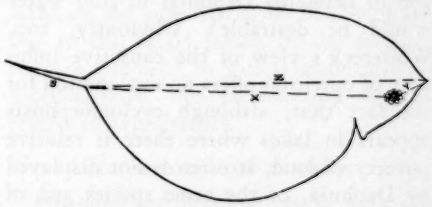

FIG. 3. DIAGRAM SHOWING METHOD OF MEASUREMENT OF DAPHNIA

In July *Daphnia longispina* virtually disappears. In September they reappear, but in October the relative frequencies of round and pointed heads, respectively, is most irregular. Thus on October 1, 1933, when the Lake was still quite new all Daphnias had pointed heads; in several collections in the fall of 1934 (September, October, and November) pointed heads occurred but rarely, the great majority being round-headed. On October 6, 1936, and on several dates in September and October, 1937, the conditions were similar to those of 1934. In 1935 only round heads occurred in January, as always; by March 19 about two-thirds of the Daphnia were helmeted; so far the story duplicated that of 1934; but, in contrast with the condi-

tions of the preceding year, round heads persisted as long as there were Daphnias in the plankton. In the collection of June 24, for example, 23 per cent of the Daphnias were round-headed. No one environmental or internal influence would seem to offer probable cause of the conditions encountered in the wild population of University Lake.

Data from experiments

Conditions of the experiments

Neither density nor viscosity of medium would seem to be available stimuli for the embryo in the brood pouch except as they might act on the mother and through her on the eggs, but experiments to be mentioned later give evidence that the embryo is not stimulated to cyclomorphic change in this indirect way. "Size of water" and geological age of the water, both mentioned as significant conditions (Gruber, 1923) are not duplicable in the laboratory and can scarcely be conceived to act as stimuli for a particular population at a particular season. Stratification of lakes is seasonal and perhaps to some extent correlated with cyclomorphosis, or both are correlated with temperature, but how stratification can act as a stimulus is not clear. So far no one seems to have recorded a correlation with content of dissolved gases or with light. The significance of the last mentioned is not to be altogether dismissed, although the experiments of McClendon (1910), and our own, in an incidental way, tend to depreciate light as the initial cause of change. We have left, then, as most likely sources of stimuli: heat, light, and the vast array of chemical substances embraced in the broad category of food supply. We have chosen first to test the influence of temperature as the most easily controlled variable among the environmental conditions and as one with which there is clearly a degree of correlation in nature.

Our Daphnia were all reared in individual culture vials, fed with a mixture of small protozoa and green algae, and kept under different conditions of temperature. In the first experiments, the control was only approximate, but in later ones, an apparatus especially designed for the purpose permitted strict and continuous control to a small fraction of a degree (Coker and Constable, 1936). Newborn were always removed from the maternal culture, to be isolated for further observation or discarded. Our particular animal possesses advantage for experimental work in that the helmet or point is unmistakable. When present it may show different degrees of development but determination of the presence or absence requires no measurement, but only observation (compare Fig. 4 with Figs. 5 and 6; see also fig. 7).

Results of the experiments

Observations on many more than 1,000 young bred from mothers in isolation form the basis for these summary statements of results. [Details of observation are given in a larger paper (Coker and Addlestone, 1938.]

(1) At temperatures below 11°C. only round heads were obtained (Fig. 4), at temperatures above 15°C. only pointed heads (Fig. 5). Mixed broods of round and weakly pointed heads (cf. Fig. 6) were obtained at intermediate temperatures in numbers to suggest a critical temperature close to 13°C. Those incubated at 20°C. have more prominent points than those incubated at 16°C. (compare Figs. 3 and 5). Hundreds of experiments in various years with diverse food supplies, conducted generally by myself, but in some cases by students—experiments in which at least a dozen different lines have been used—give no exceptions to the rule as

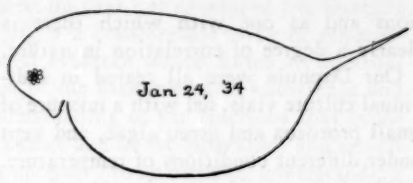

FIG. 4. WINTER FORM OF DAPHNIA LONGISPINA IN UNIVERSITY LAKE, CHAPEL HILL, N. C. (JAN. 24, 1934)

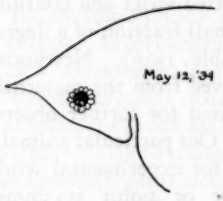

FIG. 5. LATE SPRING FORM OF HEAD OF DAPHNIA LONGISPINA IN UNIVERSITY LAKE, CHAPEL HILL, N. C., MAY 12, 1934

newborn with no points, small points or large points; this is done by regulating temperature. It should be added, however, that the only forms and sizes of helmets we have been able to induce under experimental conditions are the forms and sizes sometimes displayed by animals of the same race in nature.

On the other hand, without respect to temperature, free-living young almost invariably lost the point to become round-headed within a few molts, and this quite without respect to temperature. In a few cases and under conditions not yet analyzed, points completely or virtually lost were subsequently regained.

Thus the form of head of the newborn is definitely subject to control through regulation of temperature during incuba-

FIG. 6. FORMS OF HEAD OF DAPHNIA LONGISPINA FOUND IN UNIVERSITY LAKE IN EARLY SPRING

broadly stated. (2) When females with eggs or embryos in the brood pouch were transferred from high to low temperatures, or vice versa, the newborn with few exceptions had heads characteristic of the one or the other temperature according as the transfer was made before or after the "two-eyed" stage. (3) A few eggs removed from the brood pouch and incubated in drop cultures produced young with the same head form as was to be expected if they had developed under normal conditions. The indications seemed clear—that the influence of temperature acting directly upon the embryo, and not indirectly through the mother, governs the form of the head of the newborn. In isolation cultures one may obtain at will

FIG. 7. CONTOUR OF OCCIPUT OF HEADS OF DAPHNIA REARED AT 12°C., WITH TRACES OF HELMETS IN THE SHAPES OF BUMP, ANGLE, AND HOOK

tion, but that of the free-swimming animal in cultures is not an evident function of temperature. It does not, however, fol-

low that the fundamental conditions of development of the points on the heads is different in the two cases: the requisite conditions may be temperature plus an unknown factor which is present in all eggs, including those of females that cannot produce points on their own heads, but which may be so deficient in the culture medium as not to be available for the somatic helmet-forming cells.

Again there is a possibility of a helmet-inhibiting factor which does not affect the developing embryos nourished by yolk but which, if present in sufficient quantity, may prevent the retention of a previously formed helmet or even, under extreme conditions, prevent the adults from producing eggs that will produce helmeted young. It is now a purely hypothetical suggestion; but, if such helmet-inhibiting factor were a waste product of metabolism, a key might be found to the occasional and now inexplicable irregularities in the cycle of forms in certain waters or in certain years; to the loss of helmets in shell vials while they are retained in the lake; and to the fact that larger helmets are generally characteristic of larger bodies of water. [The few Daphnias that maintained or regained helmets during development in the laboratory were reared in larger containers.] Possibly this will also afford a clue to the alleged correlation of helmet development with geological age of the lake, if the old waters could be assumed to have developed a better condition of equilibrium of populations with less of a tendency to over-production of wastes of a particular species. This hypothetical explanation would account only for irregularities in development and maintenance of helmets, not for the origin or for the diverse forms of helmets.

At any rate, temperature is a significant factor under the conditions of laboratory experiments. We have not been able to make our Daphnias produce helmets at low temperatures and we have not had round heads born at high temperatures, excluding the middle temperatures—11°–15°C. Presumably temperature is a significant factor in nature also, but something else is equally significant both in the laboratory and in the wild; for helmet retention there is required something more than either temperature or the nutritive conditions requisite for growth and prolific reproduction.

ASPECTS OF INTERESTS IN THE PROBLEM OF CYCLOMORPHOSIS IN DAPHNIA

It would seem that the phenomena of cyclomorphosis are of special interest from several points of view:

(1) *Physiology*. Particular groups of cells respond to normal environmental changes in ways that have conspicuous external effects and they do this in a period of just a few days. To what extent can the environmental factors be subjected to experimental analysis to determine (a) which particular one is significant as to form of adult (as temperature governs form of young in our experimental race), and (b) in what degree the influence of one feature of the environment is supplemented or inhibited by that of some other, as our experimental results suggest?

(2) *Heredity*. Daphnia, to say nothing of some other Cladocera, gives an appearance of plasticity. In different environments a few rods apart, populations of the same species (as identified in winter) show seasonally characteristic differences which are hereditary. Has the environment had some effect on the genes? Woltereck claims an observable effect, persistent through several generations (Dauermodifikation) but gradually reversible in a changed environment. How do the changes in form of whole populations in

new environments, as observed by Woltereck, come into being? As a result of mutation and survival, or as a gradual process in orthogenetic fashion with inheritance of the results of progressive environmental influence? In experimental work directed at such questions, one can deal with pure lines in parthenogenetic reproduction, and also with crosses, taking advantage of the modern technique for inducing sexual reproduction at will.

(3) *Ecology and taxonomy*. Is there any connection between the facts that helmets are not readily maintained in culture dishes and that they are not characteristic of Daphnia in small ponds? What is the distribution of the innumerable special summer forms and what is their relationship to the environmental conditions in the several waters? What are the possibilities of modifying the environment to get changed forms? Genetics, physiology and ecology are peculiarly linked in this problem.

(4) *Evolution*. What has been the mode of origin of the multitude of varieties and subspecies? Is there a possibility of producing new mutations? Can Woltereck's experiments, which seemed to lead to evolutionary modifications without mutation, be repeated with comparable results?

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THE BLOOD OF ARTHROPODS

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"As a tissue or part of the body it performs many functions. . . . Nevertheless, relatively to other parts of the body, blood is a simple system . . . for, metabolic activity and irreversible chemical processes of all kinds are nearly inappreciable, and movement, except in the case of the leucocytes, is imparted from without."

Lawrence Joseph Henderson

AS A *milieu intérieur*, a complete knowledge of the blood requires an understanding of the various processes going on at different times in an animal. While this is true for all tissues it is especially so for the blood. Since, by virtue of an open vascular system, the blood of arthropods, like the lymph of vertebrates, bathes the tissues directly it is termed the haemolymph.

A. TOTAL QUANTITY AND WATER PERCENTAGE OF THE BLOOD

The blood volume of arthropods in general is, when compared with that of vertebrates, relatively large. Thus the blood of a mature silkworm larva (Richardson, Burdette, and Eagleson, '31) and of a *Chironomus* larva (Leitch, '16) is about 50 per cent of the wet weight. In the former case the average value was 0.78 cc. per larva and in the latter 0.008 cc. The wet weight of the pupa of the butterfly, *Pieris brassicae* (Brecher, '29), is about 20 per cent blood. It is a generally known fact that soon after feeding, notably in suctorial forms, the plasma volume increases markedly (Miall and Denny, 1886; Bruntz, '08a; Muttkowski, '23; Haber, '26; Wigglesworth, '31; and others) and the excess fluid is eliminated by way of the Malpighian tubules. In such cases the cuticle is capable of considerable stretch and, in extreme cases, the epicuticle becomes taut instead of wrinkled as it may be during a fast (Wigglesworth, *loc. cit*). Muttkowski (*loc. cit.*) has expressed such an increase in the plasma volume of the beetle, *Leptinotarsa*, with respect to the blood cells. Thus, the corpuscle-plasma volume ratio of a fully grown starved larva was 1:1; but in the fully fed larvae was 1:60, and in adults about 1:100! In man it is about 1:2. Among endopterygote insects the blood volume attains its zenith in the prepupal period and, among endopterygotes, in the preimaginal period (Muttkowski, *loc. cit.*).

Grapsid crabs (Baumberger and Olmsted, '28) have ten times as much blood ten days after a molt than one day before such. Similarly, the blood volume of the marine crab, *Cancer pagurus* (Paul and Sharpe, '16), is three times as great several weeks after molting than at the approach of a molt (cf. also Robertson, '37). Factors involved in such changes will be treated below. On the other hand, the blood volume of the freshwater crab, *Potamobius fluviatilis* (Herrmann, '31), does not undergo any considerable fluctuations in volume. In certain forms, such as the hermit-crab, *Pagurus* (Maluf, '38a), the maintenance of a fairly constant

blood volume is more important than the existence of a steady blood π.

The water content of the blood varies between 87 and 98 per cent (Witting, 1858; Dohrn, 1861, 1866; Halliburton, 1885a; Griesbach, 1891; Nazari, '02; Ducceschi, '02; Polimanti, '15; Kuroda, '33, '34, '34a; Drilhon-Courtois, '34; Kuwana, '37) depending upon the state of nutrition, hydration, and the rate of growth. During dry weather tardigrades (Shipley, '09) enter into a state of torpor and their watery plasma disappears. After a rain they regain their plasma and their activity.

It should be borne in mind that the blood of arthropods represents their only internal extracellular fluid and is hence equivalent to the blood, lymph, and intercellular fluid, combined, of vertebrates. This consideration lessens the differences in relative quantity between the extracellular body fluids of both phyla.

B. MICROSCOPIC STRUCTURAL ELEMENTS

(1) *Condition and distribution*

So far as known, the blood of all arthropods contains mobile cells. Muttkowski ('24a) made *in vitro* studies of the cells and bodies present in the blood of insects. The living cells present in such blood may be divided into two categories: (1) leucocytes, and (2) parasites such as bacteria (which are regularly present) and Protozoa. In cases, even nematodes were found. The leucocytes are of various grades.

The blood cells of the crayfish, *Astacus fluviatilis* (Tait and Gunn, '18), are of three types: (1) The explosive corpuscles of Hardy (1892) which are 40 to 50 per cent of the total; (2) the thigmocytes (20 to 25 per cent of the total), which are distinguished from the explosive corpuscles chiefly by emitting fine pointed processes when on non-greasy material; (3) the amoebocytes (about 30 per cent of the total) contain a granular cytoplasm and may be observed in the gill filaments to "undergo constant change of shape, sending out pseudopodia, and migrating from place to place, whereas the other two varieties remain motionless." On the other hand, the blood of *Limulus* (L. Loeb, '07) has only one type of leucocyte and hence should be taken advantage of in studies on the physiology of leucocytes. This is also true for *Daphnia* (Hardy, 1892). Glaser ('18) cultivated the blood cells of lepidopterous larvae in their own plasma.

TABLE 1

Cell counts of blood from Crustacea, insects and Limulus

ARTHROPOD	MEAN CELL COUNT/C.MM. ± STANDARD DEVIATION
Crustacea:	
Crago vulgaris	8,300 ± 2,700
Palaemonetes vulgaris	2,700 ± 800
Homarus americanus	18,700 ± 6,500
Pagurus pollicaris	26,000 ± 11,500
Cancer borealis	14,200 ± 7,200
Uca minax	12,400 ± 4,400
Xiphosura:	
Limulus polyphemus (adult)	30,000 ± 11,400
Limulus polyphemus (young)	14,600 ± 5,000
Hexapoda:	
Gryllus assimilis (cricket)	15,000 to 275,000
Other insects	15,665 to 30,000

Table 1 gives blood-cell counts made by Tauber and Yeager ('34, '36) and Yeager and Tauber ('35) on the blood from Crustacea, insects, and *Limulus*. As is apparent, there is considerable intraspecies variation and these investigators have observed a modal frequency. Such differences can be explained by the considerable variation in blood volume during various circumstances. Orthopterous larvae have 41 to 72 per cent of the mean cell

counts of the adults. *Limulus* young have about 50 per cent of the mean cell count of the adults. On the other hand, *Leptinotarsa*, *Phyllophaga*, *Photinus*, *Heliothis*, and *Neodiprion* adults have a lower value than the larvae. The total number of blood cells of arthropods, including tardigrades (Shipley, '09), increases with age.

The relative blood-cell content of arthropods is, in general, well below the value in vertebrates. Thus the erythrocyte content in an average human male is 5×10^6/c.mm. of blood and 4.5×10^6 per c.mm. in females. These values are about 500 times those found in arthropods. Tauber and Yeager ('34) believe that the very low counts given by Hardy (1892) for the crayfish and by Haber ('26) for the cockroach "may well have been due in part to loss of cells by coagulation since these authors apparently used no effective anticoagulant measures."

In the Crustacea listed above and in *Limulus* there was less than one cell undergoing mitosis in every 2,000 cells. This implies a mitotic index of less than 0.5 (or, 0.5 cell/1,000). Mitosis of leucocytes in the Crustacea has also been observed by Löwit (1889, 1891, 1891a), Hardy (1892), Kollmann ('08), and others. Cuénot (1891, 1895, 1897), Bruntz ('06, '07), and Fischer-Piette ('31) have, however, described leucocyte-forming organs in isopod, stomatopod, schizopod, and decapod Crustacea. In insects, haemolymph cell-production occurs, at least chiefly, by the mitosis of the circulating leucocytes (Yeager and Tauber, *loc. cit.*). In spiders, Franz ('03) has believed that blood cells are discharged from the internal epithelium of the heart. The "lymphatic gland" found on the crop of the lobster by Cuénot (1895) has a low mitotic index of 0.1–0.3 (Fischer-Piette, *loc. cit.*) and it has been doubted if this is adequate to account for the increase in the number of leucocytes with age but no data or calculations have been presented to support such a doubt.

(2) *Functions of the blood cells*

(*a*) *Phagocytosis* is the process of ingestion, with or without amoeboid movement, of solid material by a cell. Tait and Gunn ('18) injected powdered quartz, powdered glass, and India ink particles into the haemocoele of a crayfish and noticed that the power of ingesting particles is almost limited to the thigmopositive cells. The amoebocytes were much less phagocytic and the explosive cells not at all so. Even the phagocytic cells were incapable of ingesting simple lipoid or greasy particles, such as oil or paraffin, unless an emulsifier were present. Injection of all types of particles except greasy ones caused a great fall in the number of circulating cells. Similar studies have been made on insects by Bruntz ('08) and Métalnikov ('08). The latter found that injected bacteria are ingested, the death rate being in direct proportion to the number of non-ingested bacteria, thus showing that the phagocytes are of significance in disease (cf. also Aghar, '28 and Hollande, '30). In fact, Metschnikoff (1884) developed his classical views on disease-resistance as a result of his observations on the phagocytosis of fungus spores in *Daphnia*.

It has become an established fact that, during the histolytic occurrences in metamorphosis, the leucocytes do not aggressively disrupt the old larval cells but that they may ingest fragments of cells after the latter have become disintegrated and thrown into the haemocoele. In several species of endopterygote insects metamorphic phagocytosis has even never been observed (cf. Snodgrass, '24 and Murray and Tiegs, '35). The *in vitro* and *in vivo*

studies of Glaser ('18) demonstrate that the leucocytes do not *engulf* bacteria under any circumstances. Similar results were obtained by Friedmann and Schönfeld ('17) on peritoneal leucocytes of guinea pigs.

(*b*) *Clotting.* The phenomenon in arthropods may involve two distinct processes: (1) Agglutination of blood cells; and (2) protein coagulation. Yeager, Shull, and Farrar ('32) have distinguished three categories of insects with respect to clotting: (1) Those in which no clotting takes place; e.g. certain Homoptera, Coleoptera, Lepidoptera, and Hymenoptera such as the honeybee (Bishop, '23). (2) Those in which clotting is produced solely by leucocytic agglutinations; e.g. certain Orthoptera, Homoptera, Coleoptera, Lepidoptera, Hymenoptera, and Diptera. (3) Those in which clotting is principally a coagulation of blood proteins; e.g. certain Heteroptera, Orthoptera, Coleoptera, and Lepidoptera. They found that in the cockroach, where clotting is essentially a leucocytic agglutination, "many of the blood cells lose their fusiform or discoidal shapes, round up, form thread-like pseudopodia, agglutinate into clumps, spread out and apparently disintegrate." This type of clotting is similar to that in *Limulus*, an animal in which no plasma coagulation occurs and hence in which, contrary to common opinion, serum is not normally formed (Howell, 1885; L. Loeb, '04, '07, '10; Alsberg and Clark, '08). In fact, apart from the cell fibrin, almost the only protein in *Limulus* plasma is haemocyanin (Halliburton, 1885, 1885a; Alsberg, '14) and haemocyanin has been stated to be the only protein in the *serum* of decapod Crustacea (Halliburton, *loc. cit.*).

Geddes (1879–80) was, however, in error when he considered that the crustacean clot is merely an agglutination. In phylogeny the Crustacea are the first animals and only marine invertebrates to possess a blood plasma which yields a protein coagulum on exposed standing. Papers dealing with the coagulation of crustacean blood are numerous (Fredericq, 1879; Krukenberg, 1882; Halliburton, 1885, 1885a; Haycraft and Carlier, 1884, 1891; Hardy, 1892; Gruvel, 1894; Cuénot, *loc. cit.*; Hardy, 1892; Ducceshi, '01, '16; Bottazzi, '02; L. Loeb, '03, '05, '06; Nolf, '08; Meyers, '20; Parsons and Parsons, '20; and others). Gruzewska ('32) showed that the blood of the lobster, whether or not deprived of amoebocytes, coagulates rapidly. There are certain Crustacea, such as the crab, *Maia squinado* (Nolf, '08; Parsons and Parsons, *loc. cit.*, Kerridge, '26; Gruzewska, *loc. cit.*, Zunz, '33), and the crawfish, *Palinurus vulgaris* (Zunz, *loc. cit.*), the blood of which does not coagulate even upon the addition of vertebrate thrombin (Nolf, '08, Zunz, '33). In such forms agglutinations may occur (Bottazzi, '02a). The blood of spiders (Blackwall, 1852) clots but that of tardigrades (Shipley, '09) does not.

As regards the process of clotting, in the crayfish (Tait and Gunn), for example, the plasma undergoes two successive coagulations. The first is the result of cytolysis of the explosive corpuscles; the second is supposed to be due to the cytolysis of the thigmocytes. No coagulation results from the cytolysis of the amoebocytes, for, by injecting India ink particles into the haemocoele the number of cells in the plasma is reduced and coagulation is then only partial even though the number of amoebocytes is not reduced. Contact of the blood with any non-greasy foreign matter, such as air particles, sets up cytolysis in what are apparently the thrombin-yielding cells. When the blood is kept in fluid paraffin immediately after removal from the haemocoele the cells remain

intact and no coagulation results. A single corpuscle is capable of producing coagulation in only a limited quantity of plasma. Probably the most thorough description of the process of clotting in insects is that of Muttkowski ('24b). In the species studied, there took place the two distinct steps known to occur in the clotting of the blood of many arthropods, namely, leucocytic agglutination and the coagulation of plasma proteins (fibrin and gelatin). The coagulation of fibrin, the coagulation of gelatin, and the agglutination of the leucocytes possibly occur independently of each other due to the following reasons: (1) A clot of fibrin can occur in decaying insects several days after death, i.e. long after the death of the leucocytes; (2) agglutination is most evident in acidulated drops where little or no fibrin is formed. There were no differences between terrestrial and aquatic insects.

When potassium oxalate is added to the blood of arthropods (in Crustacea, Nolf, '08; in *Limulus*, Loeb, '10; in insects, Muttkowski, '24b) a copious precipitate of calcium oxalate is formed but the blood, in contrast to that of vertebrates, nevertheless clots with the formation of fibrin. Since calcium is unnecessary, the steps toward the formation of fibrin, must, therefore, be at a more ready-at-hand stage in arthropod blood. In vertebrates, thrombokinase does not occur freely in the blood plasma but is apparently liberated into such by rupture of tissue- or blood-cells. The already mentioned work of Tait and Gunn shows that the explosive corpuscles of crayfish liberate a coagulating factor. This substance may be thrombin, for, an assumption of the presence of thrombokinase in arthropods is quite unnecessary knowing that the removal of calcium does not hinder fibrin formation.

There are, however, certain suitable ways by which the blood of an arthropod can be prevented from clotting. Paillot ('23) found that inoculating a drop of 2 per cent nucleic acid in water containing 0.5 per cent Na_2CO_3 and 0.4 per cent NaCl into the haemolymph of an insect, the blood of which normally clots at once when exposed to the air, prevented the blood from clotting. *In vitro* studies of the blood-cells and microörganisms can thus be made. Clotting caused by leucocytic agglutination can be prevented by heating the insects at 60°C. for ten minutes (Yeager, Shull, and Farrar) and by the addition of a large quantity (4–5:1) of K oxalate or peptone to crustacean blood (Gruvel, 1894; Bottazzi, '02a; Parsons and Parsons, '23). This, in Bottazzi's interpretation, apparently prevents coalescence of the leucocytes. In *Prodenia* larvae clotting is "prevented and the insect is killed by immersion in water at 60°C. for 1 minute. There is no visible coagulation of plasma proteins after this treatment" (Babers, '38). Similar results had been reported by L. Loeb ('03a) for *Limulus* and the crab, *Libinia*. Normally autolysed hepatopancreas can inhibit clotting in several species of Crustacea and even acts intergenerically (Numanoi, '38). According to Loeb ('03a) it acts on the second clotting, i.e. the fibrin coagulation, of lobster blood.

C. SPECIFIC GRAVITY, REFRACTIVE INDEX, AND SURFACE TENSION

The specific gravity and refractive index of a given liquid varies directly with the amount of material dissolved or suspended in unit volume of the same. The specific gravity of the blood of late instars of silkworm larvae is 1.032–1.039 (Fredericq, 1881; Ducceschi, '02); that of the blood of adult *Dytiscus* and *Hydrophilus* beetles (Barrat and Arnold, '11) is lighter, being

1.025–1.027 and 1.012, respectively; and that of a worker adult honeybee (Bishop, '23) is about 1.045. Judging from the reduction in size of a drop of blood upon drying and hence from its water content, Muttkowski ('23) noted that, in general, the blood of adults is lighter than that of larvae. The specific gravity of *Limulus* plasma is 1.040 (Gotch and Laws, 1884) or 1.03 (Dailey, Fremont-Smith, and Carroll, '31) as contrasted with 1.02 for Woods Hole sea water. This is correlated with the higher concentration of solids in the plasma (= 5.77 gms. per 100 cc.) than in the sea water (= 3.41 gms. per 100 cc.). The specific gravity of the blood of the marine crab, *Platycarcinus pagurus* (Griffiths, 1892), was 1.037, being higher than that of sea water, which was 1.026.

The refractive index of the blood of a *Hydrophilus* beetle (Exner, 1891) is 1.346. Exner made use of this in his classical *in vitro* studies on the optical properties of the insect eye.

The surface tension of the plasma of the marine Crustacea, *Maia squinado* and *Palinurus vulgaris* (Zunz, '33), is, like that of teleosts and octopi, less than that of water, being about 56 dynes per cm. at 18°C. Contrary to Cosmovici ('15), Zunz noted that the surface tension of the blood plasma of mammals and selachians is greater than that of water.

D. ACIDITY

(1) *The condition*

Excessive acidity or alkalinity beyond the vital range (about neutrality) causes death. It may be that the upsetting of the poise of the oxidation-reduction systems of protoplasm, evoked by a considerable variation of acidity beyond neutrality, is the cause of death. Furthermore, an alteration in the reaction of protoplasm beyond certain limits can alter the isomeric structure of proteins and thus cause the intracellular proteinases to hydrolyze instead of chiefly synthesize protein (cf. Maluf, '37b).

The blood of insects is, in general, slightly acid in reaction (Krey, '37). The statement of Barrat and Arnold ('11) that the blood of the aquatic beetles, *Dytiscus* and *Hydrophilus*, is strongly alkalin to litmus may be dispensed with since it has never been confirmed. Thus, Muttkowski ('23) found that the blood of these beetles is neutral to litmus, i.e. has a pH of *ca.* 7.0. The blood of various grasshoppers (Bodine, '25, '26) collected under oil to prevent liberation of free CO_2 and tested colorimetrically, has a pH which varies between 6.4 and 7.0. Kocián and Špaček ('34) made colorimetric measurements of the pH of the haemolymph of various adult Coleoptera, including both the Adephaga and Polyphaga. The pH range within a given species did not exceed 0.3. The range throughout the Coleoptera was 6.2–7.2, the haemolymph of the carnivorous forms being more alkalin than that of the herbivorous ones. The pH of a given species, however, remained constant under various diets. No sex differences could be found.

The blood of honeybee larvae (Bishop, '23) has an average pH of 6.83. Higher values (pH 6.93) were found in larvae scattered in the comb and lower values (pH 6.77) in larvae in crowded combs. The difference was considered to be due to the higher atmospheric CO_2 tension in the crowded quarters which would raise the CO_2 pressure of the blood and, therefore, lower the pH. In this regard Florkin's ('34) direct measurements of the CO_2 concentration in the blood of insects should be consulted.

Tísek ('27) bred larvae of the phasmid, *Dixippus morosus*, under constant condi-

tions and found that the pH of the tissues rose continuously with age from a value of 5.5 in the third instar to 6.6 in the eighth. The value of 5.5 is probably too low and it appears that Tísek was influenced by Růžička's concept of aging. Contrary results were obtained by Muttkowski ('23) on *Leptinotarsa*, *Dysticus*, and *Hydrophilus* beetles, in which the blood is neutral to litmus in the adults and a little alkalin to such in the larvae.

Immediately before and soon after molting, the blood pH of the crayfish, *Astacus fluviatilis* (Dohrn, 1866; Damboviceanu, '30), and the crab, *Carcinus* (Jolyet and Regnard, 1877), rises from the range of 7.7–7.8 to the range of 8.0–8.2. This rise is due to a considerable increase in the combined CO_2 content (alkalin reserve) of the blood plasma, this being the result of the liberation of calcium in the blood from the old cuticle and from ingested calcareous material (cf. also Herrick, 1895; '09; Drach, '35a, '35b; Numanoi, '37). Baumberger and Olmsted ('28) have not, however, been able to find any definite connection between the pH of the blood and the molting process of grapsid crabs. It is possible that the blood of these crabs is exceptionally well buffered. The blood of *Limulus* is slightly basic (Gotch and Laws, 1884).

While the blood of insects is predominantly on the acid side of neutrality, that of decapod Crustacea (both marine and freshwater) and *Limulus* is alkalin. This difference cannot be due to a higher concentration of combined CO_2 (alkalin reserve) in the blood of the latter since such is not necessarily the case. It may be that the difference is due to a low ratio of combined to uncombined CO_2 in the blood of insects (see below).

(*2*) *Regulation of the acid-base balance*

The living processes which characterize protoplasm tend to upset its acid-base balance. Thus, CO_2 liberated into the blood during respiration, acid and alkalin residues taken in with the food, acids secreted with the digestive juices, and lactic acid liberated during muscular activity tend to deviate the pH of the blood from its narrow optimum range which approximates neutrality. The blood of insects (Krey, '37) has a fairly good buffer capacity. The various buffers by which a constant acidity can be maintained are:—

(*a*) *Blood proteins and amino acids*. These are discussed in a later section.

(*b*) *Carbonates*. In normal circumstances, the ratio of combined CO_2 to uncombined CO_2 of human blood is *ca.* 20:1. In the blood of honeybees (Bishop, '23), due to a relatively high free CO_2 concentration (i.e. CO_2 pressure), this ratio is much lower. The total CO_2 concentration of the blood of a honeybee larva is 20–30 vols. per cent, the free CO_2 concentration being 6.6 vols. per cent. Therefore, the ratio of combined to uncombined CO_2 is *ca.* 4:1. This would account for the rather low pH of the blood of insects, the combined CO_2 being of the same order as that in crustacean blood which has an alkalin pH. In the prepupa the ratio is still less and there occurs a fall in combined CO_2 during the pronounced muscular activity involved in spinning.

There is no definite difference in the total CO_2 concentration between the blood of crustaceans and insects (Winterstein, '09; Collip, '20; Parsons and Parsons, '23; Kerridge, '26; Duval, '27; Duval and Portier, '27; Drilhon-Courtois, '34; Florkin, '34; Pora, '36) the values ranging from 3 vols. per cent in the crawfish, *Palinurus* (Parsons and Parsons; Winterstein), to 89 vols. per cent in *Hydrophilus* beetles (Florkin, '34, '37a, c). Busnel and Drilhon ('37) believe that the high

total CO_2 of the blood of water beetles (*Hydrophilus*, a phytophagous animal, and *Dytiscus*, a carnivorous form) is connected with their aquatic life rather than with their diet. Because of their modes of breathing, CO_2 escape may be slower in these beetles than in other insects. The total CO_2 of *Palinurus* blood is exceptionally low but is compensated for by a low free CO_2 concentration. These animals must, hence, liberate CO_2 in accordance with only the first portion of the per cent CO_2 dissociated—CO_2 tension curve. The high pH of the blood of Crustacea is undoubtedly due to a high ratio of combined to uncombined CO_2, this being 49:1 in the estuary crab, *Telphusa fluviatilis* (Duval and Portier, '27). Drilhon ('35) has found that the total CO_2 concentration of the blood of a marine or estuary crab varies inversely with the π of the external medium and ascribes the results to the fact that gases and $NaHCO_3$ are more soluble in fresh water than in salt water.

The combined CO_2 exists mainly as $NaHCO_3$ and $CaCO_3$. Irvine and Woodhead (1888–89) assumed that Ca in the blood of crabs is chiefly in the form of phosphate. From this assumption they presumed that "the existence of alkaline phosphates would preclude the presence of soluble $CaCO_3$ in any quantity in the blood." It is, however, difficult to conceive how an insoluble compound, such as any form of Ca phosphate, can be held in the blood to any marked extent. Biedermann ('01) and Bütschli ('04) have obtained crystals of both Ca carbonate and Ca phosphate on cooling the blood of lobsters, crabs, and crayfish to 0°C.

Numerous dipterous larvae (Keilin, '21; Eastham, '25) contain deposits of $CaCO_3$ spherites in the cells of the fat-body. Such larvae are parasitic, phytophagous, or coprophagous. During the first days of metamorphosis, the $CaCO_3$ dissolves in the haemolymph and passes through the newly formed pupal cuticle into the ecdysal fluid. When this fluid is reabsorbed the $CaCO_3$ remains as a deposit on the internal surface of the puparium. Larvae of the blowfly, *Lucilia sericata* (Stewart, '34), which feed on dying tissues, exude $CaCO_3$ through their integument. The capacity of these larvae to accumulate calcium (an alkalin reserve) taken in with their food and the subsequent exudence of such makes possible an alkalinization of the surrounding medium, thus allowing predigestion of the necrotic tissues by the trypsinase eliminated with the excreta (cf. also, Hobson, '28).

(*c*) *Phosphates*. Inorganic phosphorus occurs in fairly marked quantities in the blood of arthropods (Table 4).

(*d*) *Excretory organs* eliminate uric acid and the bases, urea and ammonia (cf. Maluf, '38).

(*e*) *Haemocyanin and isohydric changes*. Kerridge ('26) has shown that oxyhaemocyanin is a slightly weaker base, hence a stronger acid, than reduced haemocyanin. Redfield and Mason ('28), '28a) have measured the acid-combining capacity and dibasic amino-acid content of haemocyanin. When haemocyanin is formed in the gill filaments, carbonic acid (H_2CO_3) will be formed from the $NaHCO_3$ (alkalin) of the blood in the gill filaments due to the momentary decrease in pH resulting from the formation of oxyhaemocyanin from haemocyanin and the consequent combination of oxyhaemocyanin with Na ions liberated from the sodium bicarbonate. The H_2CO_3 will decompose into H_2O and CO_2 and the CO_2 will be liberated to the exterior at the gill filaments. The elimination of CO_2 (and hence of H_2CO_3) will compensate for the momentary de-

crease of pH in the gill filaments resulting from the formation of oxyhaemocyanin. The pH will, therefore, not change over a measurable period, i.e. the change is isohydric. The oxygenation of haemocyanin thus actually aids in the discharge of CO_2.

At the tissues, where CO_2 is liberated into the blood and where the O_2 pressure in the blood is lower than elsewhere, the oxyhaemocyanin liberates its O_2 and becomes a stronger base (i.e. a weaker acid). Part of the carbonic acid which is formed at the tissues is neutralized by the Na liberated from the oxyhaemocyanin when the latter becomes more basic by being transformed into reduced haemocyanin and thus combines with hydrogen ions. Here too the change is thus isohydric. The transport of Na by oxyhaemocyanin enables the latter to act as a buffer compound by liberating Na in the presence of an excess of H_2CO_3, such as occurs adjacent to the cells. In this manner haemocyanin behaves similarly to haemoglobin. As Irving ('37) has pointed out, however, this buffering cannot be of much importance considering the small transport of O_2 by the blood of such animals (cf. also Maluf, '37d).

(*f*) *Carbonic anhydrase*, which catalyzes the hydration of CO_2 and the dehydration of carbonic acid, occurs prominently in the blood of mammals and is of importance in the transport and elimination of CO_2 in mammals at least (Meldrum and Roughton, '33; Roughton, '35). This enzyme is not appreciably present in the blood of Crustacea and various invertebrates (Florkin, '34c, '35; Robertson and Ferguson, '36; van Goor, '37) but has been found in the Hb-containing blood of *Chironomus* (Brinkman, Margaria, Meldrum, and Roughton, '32). In marine invertebrates, by far its greatest activity is in the gill tissues (Ferguson, Lewis, and Smith, '37). It is thus evidently of importance in the elimination of CO_2 even in invertebrates.

Prior to the discovery of carbonic anhydrase by Meldrum and Roughton (*loc. cit.*), Henriques ('29) had shown by calculation that the rate of CO_2 formation from the reaction

$$H_2CO_3 \rightarrow CO_2 + HOH$$

is too low to account for the rate of CO_2 discharge from the lungs. He hence postulated a loose combination of CO_2 with Hb (into carbhaemoglobin). This, however, could not be verified by subsequent experiments and the discovery of carbonic anhydrase came as a pleasant solution to the dilemma. The recent discoveries that many invertebrates are capable of transporting Cl ions up a steep concentration gradient by way of their integument or gills may be of significance with regard to a Cl shift for the discharge of CO_2.

E. OSMOTIC PRESSURE

Since arthropods, by virtue of their open vascular system, have only one internal extracellular fluid but nevertheless are not generally isotonic to their environment, they make excellent subjects for studies on osmoregulation and its attendant transfer of water and solutes.

(*1*) *Terrestrial and freshwater forms*

(*a*) *In their natural environment.* The Δ of the haemolymph of insects, both aquatic and terrestrial, varies between 0.47 and 0.95 with a mean of *ca.* 0.55, depending upon the species (Ducceschi, '02; Widmark, '10; Barratt and Arnold, '11; Backman, "11, '12; Polimanti, '15; Duval, '25; Portier and Duval, '27; Harnisch, '34; Drilhon-Courtois, '34; Fox and Baldes, '35; Wigglesworth, '38). The haemolymph, except in certain larvae

inhabiting sea water, is always hypertonic to the external medium, the Δ of the latter being 0.02–0.03 (Fredericq, 1898; Garrey, '05). In most cases they have a lower blood π than marine arthropods and one that approaches that of mammals including man (Δ = 0.56). Backman ('11, '12) obtained consistent results with insects in their native media and found the Δ to remain constant before and after metamorphosis. This, however, is not true for the silkmoth (Polimanti, '15), the blood Δ of which varies markedly during development.

The blood Δ of the crayfish, *Astacus fluviatilis* (Fredericq, 1898; Duval, '24; Herrmann, '31; Schlieper, '35) is about 0.80 and that of the crayfish, *Cambarus clarkii* (Lienemann, '38), varies between 0.568 and 0.718 (av. = 0.644) when the animal is in its normal medium (fresh water). According to Fritzsche ('17) the blood Δ of *Daphnia pulex* is as great as 2.0. Soon after molting and during starvation the π of the blood of freshwater decapod Crustacea (Schwabe, '33; Scholles, '33; Huf, '33) of *Daphnia* (Fritzsche), and of mosquito larvae (Wigglesworth, '38) declines slightly.

The integument of the gill filaments of certain freshwater arthropods, such as larvae of the mosquito *Aedes argenteus* (Wigglesworth, '33b), the midge *Chironomus* (Harnisch, '34; Pagast, '36; Koch, '38), and crayfish (Maluf, '37a), is extremely thin and freely permeable to water. The water that is continuously absorbed is eliminated as a markedly hypotonic and relatively copious urine (Fig. 1, E) by the Malpighian tubes, rectal cells, and antennal kidneys respectively (Wigglesworth, *loc. cit.*; Harnisch, *loc. cit.*; Herrmann, '31; Schlieper and Herrmann, '30; Schlieper, '30, '35; Peters, '35), the work of secretion evidently being supplied by energy liberated by oxidations as indicated by a rise in the oxygen consumption rate of euryhaline brackish-water forms when in fresh water and a fall in the rate when in stronger saline (Schlieper, '29, '31; Schwabe, '33; Bateman, '33; Fox and Simmonds, '33; Raffy, '34; Löwenstein, '35; Peters). More recently, Schlieper ('36) and Pieh ('36) have abandoned the latter concept after noting that the euryhaline invertebrates, *Eriocheir sinensis*, *Clava multicornis*, and *Pelmatohydra oligactis* consume oxygen at the same rate in hypertonic sea water or brackish water as in fresh water. Upon reviewing literature bearing on the subject, they came to the conclusion that the only common factor to a rise in oxygen consumption in hypotonic media is an increased water content of the tissues. A lowering of the O_2 consumption in hypotonic media is held to be due to tissue-hydration beyond the limit of tolerance. It should be noted, however, that the rate of oxygen consumption of the completely stenohaline crab, *Pagurus longicarpus* (Maluf, '38a), declines with a decrease in the tonicity of the sea water *even after osmotic equilibrium is attained and even when the lower limits of complete tolerance to dilution are not approached.* It is possible that the permeability of the surface of the above-mentioned euryhaline invertebrates becomes practically impermeable to water when in fresh water or that the osmotic work performed is relatively too small to have lent itself to measurement.

Since *some* salts are lost even in such a hypotonic urine, these must be compensated for either by feeding, as in the eel (Krogh, '37a, b) or by a secretion of salts against the osmotic gradient, as in the frog, certain freshwater fish, crayfish, earthworms, and the anal gills of certain mosquito and chironomid larvae (Krogh, '37a, b, c, d; Koch and Krogh, '36; Koch, '38; Wigglesworth, '38; Maluf, '39a, b).

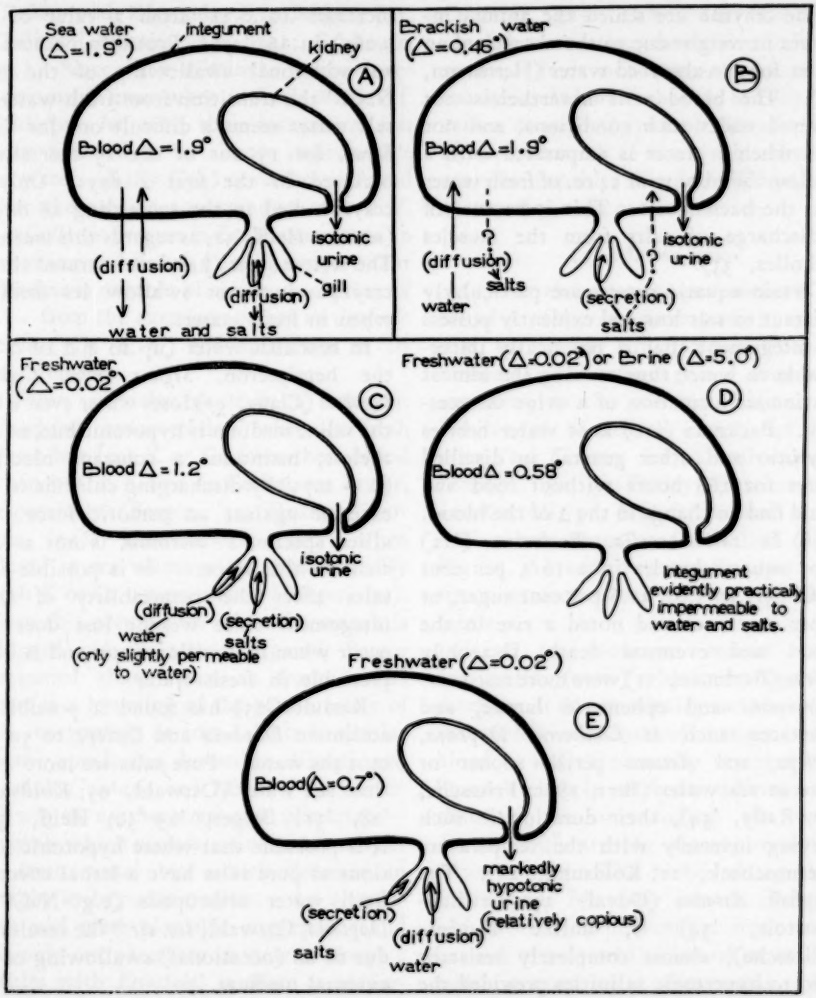

FIG. 1. SCHEME INDICATING HOW ADULT MARINE ARTHROPODS MAY HAVE INVADED FRESH WATER BY WAY OF THE BRACKISH WATER ESTUARIES

(A) Completely stenohaline (poikilosmotic) form confined to the sea and incapable of inhabiting brackish water (e.g. *Homarus*, *Palinurus*, *Pagurus*). (B) A partially homoiosmotic form confined to the sea and brackish water and incapable of inhabiting fresh water (e.g. *Carcinus maenas*, *Mesodotea entomon*). (C) An incompletely homoiosmotic form nevertheless capable of inhabiting fresh water, brackish water, or the sea (e.g. *Eriocheir sinensis*, *Telphusa fluviatilis*). (D) Almost completely homoiosmotic form capable of inhabiting and breeding in brine or fresh water (e.g. *Culex mariae*). (E) Specialized freshwater form incapable of living in the sea but capable of living indefinitely in isotonic balanced salinel without a marked change in the blood π. It cannot live in the sea probably mainly because of the fact that its kidneys invariably secrete a blood-hypotonic urine (e.g. *Cambarus*).

When the external orifices of the kidneys of the crayfish are sealed the animal increases in weight due to the absence of an outlet for the absorbed water (Herrmann, '31). The blood π is nevertheless not lowered under such conditions; and not even when a pincer is amputated with a resultant admission of 14 cc. of fresh water into the haemocoele. This is because of a discharge of salts from the muscles (Scholles, '33).

Certain aquatic insects are particularly resistant to salt loss and evidently possess an integument that is practically impermeable to water thus making the almost continuous formation of a urine unnecessary. Backman ('12) kept water beetles (*Dytiscus* and other genera) in distilled water for 288 hours without food and could find no change in the Δ of the blood.

(*b*) *In saline media.* Backman ('12) kept aquatic beetles in 2 to 3 per cent NaCl (3.7 to 5.6), 31.6 per cent sugar, or 6 per cent urea and noted a rise in the blood and eventual death. Dragonfly larvae (Backman, '11) were more resistant. *Chironomus* and ephemerid larvae, and Crustacea such as *Cladocera*, *Daphnia*, *Cyclops*, and *Astacus* perish sooner or later in sea water (Bert, 1871; Fritzsche, '17; Raffy, '34), their duration in such varying inversely with the temperature (Dernoscheck, '11; Koidsumi, '28). The crayfish *Astacus* (Duval, '25; Drilhon-Courtois, '34) is, unlike *Daphnia* (Fritzsche), almost completely resistant even to hypertonic salinities provided the Δ of the latter is less than 1.85. Under such conditions the urine becomes scantier, its Δ increases but always remains considerably hypotonic to the blood, and the blood Δ increases somewhat. *Camharus* (Lienemann, '38) has evidently a greater osmoregulatory capacity than *Astacus* since, when the former is placed in blood-isotonic NaCl, there is no appreciable rise in its blood Δ but the urine Δ increases to 0.32 (from a value of *ca.* 0.065) in 16 days. Probably because of an occasional swallowing of the pure NaCl "the transition from fresh water to salt water seems a difficult one for *Camharus*, for 15 out of the 19 mortalities occurred in the first 4 days. Only 4 crayfish died in the succeeding 28 days" (see also Helff, '31, as regards this matter). The writer ('39a) has demonstrated that a crayfish does not swallow its medium when in fresh water.

In brackish water (up to a Δ of 0.88) the hemipteron, *Sigara* (syn. *Corixa*) *lugubris* (Claus, '37) loses water even when the saline medium is hypotonic but, nevertheless, maintains a constant blood π ($\Delta = 0.75$) by discharging chlorids to the exterior against an osmotic force. An allied species, *S. distincta*, is not as efficient in this respect. It is possible that salts affect the permeability of their integument since weight loss does not occur when in distilled water and is inappreciable in fresh water.

Ramult ('25) has found it possible to acclimate *Daphnia* and *Cyclops* to 50 per cent sea water. Pure salts are more toxic than sea water (Ostwald, '05; Koidsumi, '28, '31; Berger, '29–'30; Helff, '31). It is probable that where hypotonic solutions of pure salts have a lethal effect on fresh water arthropods (e.g. NaCl on *Daphnia*, Ostwald, *loc. cit.*) the results are due to an (occasional) swallowing of the external medium.

(*c*) *Drying.* If the aquatic beetle, *Dytiscus* (Backman, '12) is kept in dry air for several hours its blood Δ can increase to 1.4 or more.

(*2*) *Estuarine crabs*

Telphusa fluviatilis, *Eriocheir sinensis*, and *Sesarma* n. sp. are capable of living indefinitely in both fresh water and sea

water even without being acclimatized (Dakin and Edmonds, '31; Berger, '31; Drilhon-Courtois, '34, '34a; Schlieper, '35). Since they eliminate a blood-isotonic urine even when in fresh water (cf. Schlieper, *loc. cit.*), their integument has been assumed to be almost impermeable to water. Raffy ('34) nevertheless found that the oxygen consumption rate of *T. fluviatilis* is greater in fresh water than in sea water and Krogh ('37c) has noted that *Eriocheir* is capable of active absorption of Cl^- from the exterior against an osmotic force (Fig. 1, C) and according to its requirements.

These animals maintain a constant blood-ion concentration when in fresh water but lose K or Ca from their blood when put in K-free or Ca-free sea water, respectively (Berger, '31; Drilhon-Courtois, '34). The converse occurs when placed in sea water with an abnormally high K or Ca concentration (Berger, '31). Since this occurs even when the mouth is plugged and the anus is ligated, Berger suggested that, when in fresh water, there is a lowering of the permeability of the integument to ions. This is similar to the conclusion drawn by Adolph and Adolph ('25–26) and Maluf ('39b) with regard to earthworms and planarians—animals which maintain a constant weight in fresh water but which decrease in weight in hypotonic saline. An alternative and more plausible suggestion (and the only one necessary in view of Krogh's results with *Eriocheir*) is that, as in *Carcinus maenas*, these crabs are capable of actively withdrawing salts from hypotonic media.

When in sea water, the blood π of the estaurine crabs rises (Drilhon-Courtois, Berger) from its state ($\Delta = 1.18$) in fresh water to approximate isotonicity with the sea water, although the increase is somewhat buffered by a marked decrease in the concentration of blood protein (Drilhon-Courtois, '34). This is also true of the crayfish and the euryhaline crab, *C. maenas*. It is not known how the estuarine and shore crabs (see below) maintain a constant hypotonic blood π when in sea water. It is conceivable that they may be capable, like eels (Keys, '31), of secreting salts to the exterior.

(3) *Marine forms*

(*a*) *In their natural environment.* The blood Δ of marine arthropods is, in general, very nearly equal to that of the environment (= 1.80–2.4) and thus varies according to the salinity of the marine habitat (cf. Macallum '02–'03, '26; Fredericq '04; Garrey '05; Duval '24, '25; Schlieper '30, '35; Dailey, Fremont-Smith and Carroll '31; Maluf '38a and numerous others mentioned in this paper; Fig. 1, A) and is generally over three times greater than that of freshwater forms.

There are, however, certain species (euryhaline forms) which are capable of dwelling in an osmotically varied environment without as marked changes in their blood π and of normally maintaining a blood π that is markedly different from that of the surrounding sea water. Among such are the already mentioned estuary crabs. The blood of the Baltic Sea isopod, *Mesodotea entomon* (Bogucki, '32), which cannot endure fresh water, has a Δ of 1.07 while that of its environment is only 0.41. Since this animal cannot live in fresh water or extremely diluted sea water, it appears that, as in *Carcinus*, it actively secretes salts from the exterior into its blood. The π of the blood of the crabs *Carcinus maenas* and *Heteropanope tridentata* (Duval, '25; Margaria, '31; Bateman, '33; Schwabe, '33; Otto, '34) which are capable of living indefinitely in brackish water, is generally

higher than that of the external medium even when the latter is regular sea water. Other shore crabs, such as *Eriphia spinifrons* (Schwabe), *Pachygrapsus* (Baumberger and Olmsted, '28; Schwabe), *Heloecious cordiformis*, *Leptograpsus variegatus*, *Sesarma erythrodactyla* (Dakin and Edmonds, '31; Edmonds, '35) have a blood π (Δ = *ca.* 1.96) which is maintained below that of the surrounding sea water (Δ = *ca.* 2.14).

The blood π of Crustacea (Widmann '35–'36) falls during starvation or during rise in temperature.

The mechanism of osmoregulation in *C. maenas* (Fig. 1, B) has been the subject of an admirable study by Nagel ('34) in Carl Schlieper's laboratory at Marburg. The salt concentration of the urine of this species is equal to that of the blood but, probably due to the presence of quantities of organic material in the latter, the π of the blood is higher than that of the urine when the animal is in brackish water. In this connection it is of interest to note that the protein concentration of the blood of *C. maenas* (Drilhon-Courtois, '34) varies inversely with the π of the external medium. It is nevertheless clear that the kidneys of this animal have no osmoregulatory function as far as the maintenance of a constant mineral concentration in the blood is concerned. Therefore, there must be another factor which maintains a constant hypertonic blood π in spite of salt loss through the kidneys. Nagel's experiments show that the integument (presumably of the gills) can secrete salts into the blood from a hypotonic medium according to the extent of salt depletion.

At the approach of molting, the blood π of crabs and isopods (Baumberger and Olmsted, '28; Huf, '33; Schwabe, '33; Scholles, '33; Widmann, '35–'36; Robertson, '37) rises markedly. Taking into consideration that the glycogen content of the hepatopancreas of *Carcinus maenas* (von Schönborn, '10) is more than twice as great just prior to molting than after, Baumberger and Olmsted suggested that the rise in the blood π at the approach of molting is due to the breaking up of glycogen in the hepatopancreas into glucose and lactic acid, which would be released into the blood. But, as a result of analyses, Baumberger and Dill ('28) later found "that in no case could the conversion of glycogen to sugar sufficiently raise the osmotic pressure of the blood to account for the freezing point depressions observed." They could, however, explain the subsequent decline (see also Schwabe, '33 and Scholles, '33 for other species) in the blood π sheerly on a dilution basis, i.e. as the result of the absorption of water but not of salts. The site of water intake was not determined but it was assumed to occur *per os*. This, however, does not seem probable to the writer since the blood π would not fall well below that of the external medium because of salts which would have to be absorbed through the gut. The imbibition of water increases the blood pressure and thus aids ecdysis and the expansion of the new integument. Almost two decades earlier von Schönborn ('11) had observed that the percentage of total solids in the whole body of newly molted individuals of the crab, *Maia squinado*, is about one-third that of individuals within intermolting periods.

Since, with the possible exception of a few brine species (see below), the integument of all marine arthropods is permeable to salts (cf. Berger, '31; Bethe, '34; Maluf, '38a), it is no wonder that they cannot withstand isotonic unbalanced saline solutions (see, for instance, Loeb, '03; Barnes, '32, '34, '35).

(*b*) *In hypotonic media*. Apart from the

above-mentioned euryhaline or partially homoiosmotic forms, the stenohaline (completely poikilosmotic) forms are capable of a certain degree of dilution. But just as freshwater arthropods cannot exist with a blood π as great as that of sea water, marine forms cannot endure a blood π as low as that of the freshwater denizens. The reasons for such intrinsic differences are not known although it appears that, in general, the marine inhabitants cannot withstand anywhere near as great dehydration as they can dilution (Maluf, '38a), i.e. they are living within their upper limits of osmotic pressure. Even among marine forms, resistance to dilution is not uniform. Thus, the hermit crab, *Pagurus longicarpus* (Maluf, '38a), can continue to have a normal heart rate in 50 per cent sea water while the heart of *Aplysia* (marine snail), *Octopus*, and the prawn, *Palinurus* (Fredericq, '22), ceases to beat instantaneously if perfused with 50 per cent sea water even though the sea water at Naples is considerably hypertonic to that of Long Island Sound. The latter species are probably less subject to dilution in nature. A marine amphipod, *Gammarus* (Loeb, '03), will die in a short time in 1/10 sea water but can permanently withstand 1/2 sea water. The isopod, *Ligia oceanica* (Tait, '16; Bateman, '33), swells and dies in 1/2 sea water. The lobster, *Homarus americanus* (Garrey, '05), dies within six hours in 1/2 sea water ($\Delta = 1.02$) when the blood Δ arrives at 1.32. The latter value is considerably higher than that of its freshwater relative, the crayfish. When the blood Δ of *Limulus* (Garrey, *loc. cit.*) equals 0.90° the gill filaments burst owing to excessive internal pressure. The soft abdomen of the hermit crab, *Pagurus* (Maluf, '38a), often bursts in 1/2 sea water.

In all cases the dilution curves are logarithmic indicating an integument freely permeable to water.

Summing up, *arthropods which can live indefinitely in the sea* may be categoried thus with regard to their status in hypotonic media:

(i) *Those which are practically independent of hypotonic media;* e.g. larvae of the mosquito, *Culex mariae*—in truth of freshwater ancestry.

(ii) *Those the blood π of which is decreased but only to a certain level and which can live indefinitely in fresh water without acclimatization;* e.g. the estuary crabs.

(iii) *Those the blood π of which is decreased only to certain level in brackish water but which, as far as is known, cannot live indefinitely in fresh water or extremely dilute sea water;* e.g. the shore crabs, *C. maenas* and *Sesarma erythrodactyla*.

(iv) *Those entirely incapable of osmoregulation;* e.g. *Maia*, *Pagurus*, *Platycarcinus*, *Homarus*, *Limulus*.

(*c*) *In hypertonic media.* Certain arthropods, of freshwater ancestry, are known to live and breed in a markedly hypertonic medium such as brine; e.g. the Diptera *Stratiomys* (Henneguy, '04), *Aedes zammittii* (de Vogel, '07), *Culex mariae* (Sergent, '09), and the branchiopod, *Artemia salina* (Medwedewa, '27). A rise in the π of the brine from $\Delta = 2.65°$ to $\Delta = 4.98°$ produces a rise in the blood π of *Artemia* from $\Delta =$ 0.74° to only 0.80°. *Artemia* is one of the few branchiopods which has adopted a marine habitat. Herbert Warren (cf. Boon and Baas-Becking, '31) has shown that *Artemia* has "in the muscular mechanism of its loop-shaped proctodaeum a most efficient means of closure of the gut." It can thus live for days even in solutions of potassium permanganate, potassium bichromate, and potassium nitrate. Unlike its dipterous brine neighbors, *Artemia* (Medwedewa) is incapable of inhabiting hypotonic media. This may be due to the

fact that it has an integument permeable to salts and that it possibly has learnt to secrete salts only to the exterior and not to the interior, against an osmotic force.

Crabs, such as *C. maenas* and *E. spinifrons*, which have been noted to be capable of considerable osmoregulation in a hypotonic medium are, however, almost as susceptible to hypertonic media as *Maia* or *Platycarcinus*. The reason for this becomes clear when their method of osmoregulation and the fact that Crustacea cannot excrete a urine hypertonic to the blood are borne in mind.

(*d*) *Drying* raises the blood π (Garrey, '05; Bateman, '33). When the chlorid concentration of the blood of *C. maenas* (Bateman) attains the value of 0.815 M, whether because of drying or of sojourn in a hypertonic medium, the crab dies thus indicating that the effects of drying can be the same as those of hypertonic media.

F. SUBSTANCES OF THE HAEMOLYMPH

(*1*) *Mineral salts*

The fact that the blood of most marine Crustacea is isotonic to the environment does not imply that the proportions of the various major ions are the same in both the external and internal media. Table 2 shows that among marine forms (except the Baltic Sea isopod, since that sea has a relatively low salt concentration, and with the exception of *Palinurus vulgaris*) the [Na] is somewhat lower in the blood than in the sea water; the [Mg] is much lower in the blood while the [Ca] and [K] values are a little higher in the blood. The [Cl] of the blood is a little less than that of the environment. This condition is exemplified thus in Macallum's ('26) fascinating paper (Na being arbitrarily taken as 100):

ELEMENT	Na	K	Ca	Mg	Cl	SO_4
Ocean water.....	100	3.61	3.91	12.1	180.9	20.9
Homarus blood...	100	3.73	4.85	1.72	171.2	6.67

The relative differences in ionic concentration are evidently, at least mainly, due to selective secretion by the kidneys rather than to selective absorption by way of the gut, as shown by plugging the mouth and ligating the anus (Scholles, '33). The relative mobilities of the passage of the ions through the integument can scarcely be a factor, as Pantin ('31) suggests, partly because these differences might be cancelled by the same relative mobilities through the kidney membranes. Robertson ('37) has pointed out that the presence of colloids in the blood accounts, at least partly, for the higher value of Ca in the blood of *C. maenas* than in the surrounding sea water.

The blood of most marine arthropods is raised to the level of that of sea water by other blood constituents, such as urea, amino acids, proteins, trimethylamine (?), and glucose. But Myers' ('20) determinations exemplify the fact that the major component of the blood π is due to the minerals in solution and not to organic constituents as in elasmobranchs (Myers) and insects (see below). The total mineral salt concentration of the blood of freshwater Crustacea is lower than that of marine forms but the [Ca] is about equal in both groups. Calcium is necessary for the formation of the cuticle and it is well known that crayfish do not inhabit freshwater bodies deficient in Ca; e.g. those of Long Island, N. Y. They undoubtedly obtain most of their Ca supply by feeding on Ca-rich material when renewing their cuticle.

The concentration of *total* phosphorus in the blood of the crab, *Maia squinado* (Drilhon, '33b), remains approximately

constant at all stages. Upon molting the mineral P undergoes a decline, being probably then utilized in the formation of the tricalcium phosphate of the new cuticle—the principle mineral salt of such (Herrick 1895, '09)—and probably not as Drilhon (now Drilhon-Courtois) would have us suppose, converted into organic P. Even though the blood of decapods is, by dilution, considerably augmented in volume after molting, the [Ca] nevertheless remains constant (Paul and Sharpe and Damboviceanu). This is probably due to a liberation of Ca stored in the hepatopancreas (cf. Maluf, '37b) and muscles (Scholles, '33).

The blood of terrestrial forms (insects) is relatively rich in K and inorganic P but very poor in Cl and Na (Table 2). When compared with mammalian blood it has much less Na and Cl but much more K, Ca, P, and particularly Mg. Assuming the analyses to be accurate, it is at present inexplicable why insect organs are more sensitive to deficient Na and excess K in the perfusion medium than are vertebrate organs (cf. Clarke, '27; Hobson, '28; Maluf, '38c). The reason for this marked discrepancy may be due to the fact that in all cases the *total* [K] of the blood was determined and not solely the *ionized* [K]. Nevertheless, even if all the purine in the blood were considered to be in the form of the dibasic salt, K_2 urate, this would account for only about 7 mg. per cent of the blood K leaving the remaining about 120 mg. per cent unexplained for. It is possible that some of the K is united to amino acids and proteins, with which the blood of insects is especially rich.

The blood of insects (Muttkowski, '23) contains Cu and Fe in unknown quantities. The total mineral concentration of the blood can account for only 1/4 of its π (Bishop, Briggs, and Ronzoni, '25), being much lower than that of marine arthropods, freshwater Crustacea, and mammals; and the elements are not present in the same relative proportions as found in sea water, marine arthropods, and vertebrates. Most of the blood π of insects is due to organic molecules, chief of which are the abundant free amino acids (Table 4). While the Na, reckoned as NaCl, explains only *ca.* 4.5 per cent of the total molecular concentration of the blood of moths (Drilhon, '34), that of marine Crustacea accounts for 90–95 per cent of such. The high total [K] of the blood of insects may bear some relation to their vegetable diet and its probable significance has been pointed out above. It is only fair to say that we know practically nothing of the *ionic* [K] in insect blood. The relative concentration of elements in the blood of a crayfish and an insect are nevertheless shown below (Na arbitrarily taken as 100). Even with [Na] used as a reference, the composition of the blood of insects departs widely from that of sea water.

ELEMENT	Na	K	Ca	Mg	Cl
Cambarus blood...	100	5.27	4.53	0.71	47.2
Honeybee larva...	100	730	111	161.5	895

(2) *Carbohydrates*

So far as known, glucose is the only form in which carbohydrate is transferred from the gut to the tissues. While professing to be analyzing the [glucose] of the blood of various arthropods, Morgulis ('23), Myers ('20), Blumenthal ('27), Beutler ('36), and others were actually including all other reducing substances in the blood (Table 3). The methods used by them do not take into consideration disturbing factors (e.g. glutathione, ascorbic and uric acids), which Hemmingsen ('24) and Florkin ('37e)

TABLE 2

Mineral content of the blood of arthropods in their natural media

(Mgm./100 cc.)

ARTHROPOD (ADULT UNLESS OTHERWISE STATED)	Na	K	Ca	Mg	Cl	P (INORGANIC)	S (NON-PROTEIN)	Fe	INVESTIGATORS
Terrestrial (insects):									
Pieris brassicae (pupa).	traces	137.8	33.0	56	59.5	66.0	—	—	Brecher ('29)
Deilephila euphorbiae (larva).....	—	—	41.0	43.5	48.6	12.0	—	5.8	Heller and Moklowska ('30)
Prodenia eridania (larva)	51.2	155.0	36.8	17.2	119.8	17.6	44.4	—	Babers ('38)
Various lepidopterous larvae and pupae...	—	—	—	—	26–97	—	—	—	Portier and Duval ('27)
Dytiscus marginalis....	—	125	—	—	224	—	—	—	Portier and Duval ('27), and Busnel and Drilhon ('37)
Pupae of various moths (av.).....	14.7	164	30.5	—	—	22.5	—	—	Drilhon ('34)
Honeybee larva.....	13	95	14.4	21	116.5	31	traces	—	Bishop, Briggs, and Ronzoni ('25)
Leptinotarsa decimlineata	—	111	—	—	—	—	—	—	Busnel and Drilhon ('37)
Hydrophilus piceus.....	—	828	—	—	—	—	—	—	Busnel and Drilhon
Fresh-water:									
Astacus fluviatilis (crayfish).....	322	14.04	66.6	17.0	—	—	—	—	Bernard ('33)
A. fluviatilis.....	—	—	55	—	—	—	—	—	Damboviceanu ('30)
A. fluviatilis.....	488	19.0	56.0	—	—	0.9	—	—	Drilhon-Courtois ('34, '34a)
A. fluviatilis.....	—	20.0	42.0	6.0	691.0 (copper = 27.4)	21.4	20.1	21.2	Schlieper ('35) and data of Dohrn (1866)
Cambarus clarkii (crayfish).....	877	46.2	39.7	6.2	414.3	0.47	—	—	Lienemann (1938)
Telphusa fluviatilis (in fresh water).....	775	33	72.3	—	—	1.0	—	—	Drilhon-Courtois (*loc. cit.*)
T. fluviatilis (in sea water).....	1,220	63	96.5	—	—	0.3	—	—	Drilhon-Courtois
Marine:									
Mesodotea entomon (of the Baltic Sea).....	464.0	24.0	50.0	28.0	730.0	4.0	23.0	—	Bogucki ('32)
Limulus polyphemus (Woods Hole).....	1,016	50.1	38.9	118.5	1,774	12.2 (copper)	—	0.68	Dailey, Fremont-Smith, and Carroll ('31) and data of Gotch and Laws (1884)
Cancer productus *C. antennarius*.....	1,757	—	52.1	—	—	—	—	—	Meyers ('20)

TABLE 2—*Concluded*

ARTHROPOD (ADULT UNLESS OTHERWISE STATED)	Na	K	Ca	Mg	Cl	P (INORGANIC)	S	Fe	INVESTIGATORS
Marine:—*Continued:*									
Carcinus maenas	1,300	51.0	50.0	94.0	2,160	—	—	—	Duval ('24), Bethe ('28–'29), Schlieper
Various crabs	1,300	—	—	—	—	—	—	—	Duval
Maia squinado	—	—	—	—	—	20–52	—	—	Drilhon ('33)
Palinurus vulgaris	2,180	98	98	54	2,160	—	—	—	Schlieper
Homarus vulgaris	1,300	—	—	—	—	—	—	—	Duval
H. americanus	903	33.7	43.8	15.6	1,547	—	24	—	Macallum ('26)
H. americanus	987	53.8	97.2	20.4	1,575	—	13.4	—	Cole *et al.* ('38)
Crabs and lobsters	—	—	—	—	—	6.50	—	—	Gautrelet ('02)
External media:									
Naples Bay	1,960	43	45	219	2,227	—	—	—	Schlieper
Woods Hole	1,004	—	—	—	1,831	—	—	—	Dailey, Fremont-Smith, and Carroll
" "	880	41.2	42.8	130.0	1,835	0.67	87.1	—	Page ('27)
Baltic Sea	188	7	11	24	360	—	19	—	Bogucki
Tap water (Ithaca, N. Y.)	13.6	trace	4.4	1.1	0.7	0.12	—	—	Lienemann ('38)

have shown to be of overwhelming magnitude in the blood of crayfish and insects, respectively. Hemmingsen allowed yeast cells to hydrolyze the glucose in the blood and compared the results before and after yeast action. His data on crayfish make the presence of glucose in the blood of this animal, at certain periods at any rate, very doubtful. One-half to five-sixths of the total reducing substances in the blood of various species of Lepidoptera (Kuwana, '37; Babers, '38) and of the beetle *Hydrophilus* (Florkin, '37e) was not glucose. On the other hand, all the reducing material of the blood of *Limulus* (Dailey, Fremont-Smith, and Carroll, '31; Fremont-Smith and Dailey, '32) and various decapod Crustacea (Florkin, '37e), is fermentable by yeast and not appreciably affected by HCl hydrolysis. Demianowski and Prokoffjewa ('35), Florkin ('36b, '37b) and Kuwana (*loc. cit.*) have determined the variations in glycaemia of the silkworm at various postembryonic stages.

The [glucose] of the blood of some Crustacea (*Carcinus*, *Portunus*) declines during short starvation (Stott, Hemmingsen). Roche and Dumazert ('35) have, however, noted that the glucose concentration of the blood of *Cancer pagurus* is not appreciably modified by a fast. There is, thus, evidently a regulation of glycaemia in some crabs. Furthermore, Stott and Hemmingsen were really determining *total* copper-reducing substances in the blood and not merely glucose. Under oxygen deficiency, in which the rate of glucose oxidation is probably not as great as under normal conditions, the [glucose] rises to levels comparable to those of well-fed animals (Stott). According to Heller and Moklowska ('30) the [glucose] of the blood of Lepidoptera rises during the pupal period. On the contrary, Kuwana ('37), who applied yeast fermentation, found that the sugar of the blood of the silkworm falls to zero at the beginning of metamorphosis and remains at zero during the pupal stage. The [glucose] of the blood of mature

TABLE 3

Carbohydrate and total reducing substances in the blood of arthropods

(Mgm./100 cc.)

ARTHROPOD	TOTAL REDUCING SUBSTANCES (AS GLUCOSE)	"FREE" SUGAR (CALCULATED AS GLUCOSE)	GLYCOGEN	COMBINED OR PROTEIN SUGAR AND POLYSACCHARID LOWER THAN GLYCOGEN	INVESTIGATORS
Xiphosura:					
Limulus polyphemus	11–22	11–22	—	—	Dailey, Fremont-Smith, and Carroll ('31)
Crustacea:					
Cancer productus, *C. antennarius*	90	—	—	—	Myers ('20)
Maia squinado	20	—	—	—	Drilhon ('33)
M. squinado (prior to molt)	185	—	—	—	Drilhon
Carcinus maenas (starved 8 days)	6	—	—	—	Stott ('32)
C. maenas (fed)	60±	—	—	—	Stott
Palinurus argus	19–71	—	—	—	Morgulis ('23)
Cancer pagurus	—	10–30	—	—	Roche and Dumazert ('35)
Astacus fluviatilis	8–10	0–3	—	—	Hemmingsen ('24)
Various decapods	—	7–26	—	—	Florkin ('36c, '37e)
Insecta:					
Grasshoppers:					
Romelea microptera (larva)	34.2–49.4	—	—	—	Blumenthal ('27)
Melanoplus femur-rubrum	30.6–41.9	—	—	—	Blumenthal
M. differentialis	31.0–45.9	—	—	—	Blumenthal
Chortophaga viridifasciata	34±	—	—	—	Blumenthal
Encoptolophus sordidus	36.4	—	—	—	Blumenthal
Lepidoptera:					
Phalera bucephala (larva)	126.0	39.0	—	—	Hemmingsen
Deilephila euphorbiae	127.0	—	—	—	Heller and Moklowska ('30)
Prodenia eridania (larva)	65.9	11.1	3.29	—	Babers ('38)
Various species (at different periods after feeding)	58–450	—	—	—	Hemmingsen
Bombyx (larva)	24–43	0.4–4	—	—	Kuwana ('37)
Bombyx (metamorphosing)	24–50	0.0	—	—	Kuwana
Hymenoptera:					
Apis mellifica (feeding larva)	203±	—	—	—	Bishop, Briggs, and Ronzoni ('25)
A. mellifica (spinning larva and pupa)	775±	—	—	—	Bishop, Briggs, and Ronzoni ('25)
A. mellifica (mature feeding larva)	—	685	10>	2,785–3,035	Ronzoni and Bishop ('28)
A. mellifica (prepupa)	—	154	2,800	1,806	Ronzoni and Bishop ('28)
A. mellifica (pupa)	—	20–80	—	—	Ronzoni and Bishop ('28)
Coleoptera:					
Hydrophilus piceus	—	6–31	—	—	Florkin ('37e)

honeybee larvae is relatively great (Table 3) and declines to about 1/6 of its value during the prepupal and pupal periods. This decrease is accompanied by a lowering of the blood π. The blood sugar is thus vehemently drawn upon as a source of energy during spinning and metamorphosis. Also, at this time the cells of the fat-body begin to disintegrate and liberate large quantities of glycogen into the blood (Table 3), raising the glycogen of this fluid from an inappreciable quantity (i.e. < 10 mgm./100 cc.) to 2,800 mgm./100 cc. The blood of the larva and prepupa contains carbohydrate reserves in the form of protein-combined sugar and polysaccharid lower than glycogen (Table 3). These must be hydrolyzed to glucose, by carbohydrates in the blood, before they can be utilized by the cells. Ronzoni and Bishop have pointed out that the presence of complex carbohydrates in the blood, during the onset of metamorphosis, allows a more rapid utilization of carbohydrate than would be possible without a marked rise in the blood π which would follow a release of glucose from the tissues if glucose were the principal carbohydrate of the blood.

At the molting period the glycogen stored in the hepatopancreas of decapod Crustacea is broken down to glucose which is liberated into the blood. At this time, therefore, the [glucose] of the blood is extraordinarily high (Drilhon, '33a). The glucose is undoubtedly partly utilized in the formation of the chitin (a polymerized glucoseamine) of the newly forming skeleton (cf. Maluf, '37b).

Contrary to what happens in vertebrates, injected insulin has no effect on the rate at which sugar disappears from the blood of Lepidoptera and crayfish (Hemmingsen, '25) and even increases the total reducing power of the blood of such. No convulsions are produced. Insulin does not exist in the glycogen-rich tissues of oysters (Long, '37). It is possible that, among invertebrates, other hormones take the place of insulin and adrenalin in evoking a liberation or storage of glucose according to the immediate demands of the animal.

(3) *Lipids*

The blood of the honeybee larva (feeding or spinning) contains about 453 mgm. of total fat per 100 cc. (Bishop, Briggs, and Ronzoni). At the time of metamorphosis, when the fat-body cells rupture and liberate their inclusions into the blood, the fat content of the latter rises enormously. The [cholesterol] of the blood of feeding honeybee larvae is 35 mgm./100 cc. (Bishop, Briggs, and Ronzoni) and 5.7 mgm./100 cc. of the blood of the crabs, *Cancer productus* and *C. antennarius* (Myers, '20). In comparison with mammalian blood the cholesterol value is much lower but the fat value is ordinarily higher.

(4) *Proteins and free amino acids*

While the [protein] of the blood is somewhat lower than that of mammals, the [free amino acid] of the blood of arthropods far exceeds that of the latter. The [amino acid] of the blood of insects is prodigious, being well above that of the Crustacea. It has already been pointed out that the amino acids account for the greatest component of the blood π of insects. The [amino acid] of the blood of the pupae is highest and is probably the result of proteolysis occurring during histolysis.

The plasma proteins act as buffers, tissue builders (especially during metamorphosis), agents of clotting, enzymes, and oxygen transporters.

(*a*) *The haemocyanins.* (*i*) *General.* The presence of a marked quantity of copper

TABLE 4

The protein and free amino-acid content of the blood

(Mgm./100 cc. = protein or amino-acid nitrogen × 6.25)

ARTHROPOD (ADULT UNLESS OTHERWISE SPECIFIED)	PROTEIN	FREE AMINO ACIDS	INVESTIGATORS
Lepidoptera:			
Deilephila euphorbiae (mature larva)	5,156–*ca.* 6,000	1,062.5	Heller and Moklowska ('30)
Cossus cossus (larva)	—	14,040	Duval, Portier, and Courtois ('28)
Bombyx mori (larva)	2,760–5,165 (rises throughout larval life and decreases during beginning of metamorphosis)	—	Nazari ('02), Florkin ('37a)
Attacbus cynthia (pupa)	—	20,220	Nazari
Sphinx ligustri (pupa)	—	19,300	Nazari
Saturnia pyri (pupa)	—	17,100	Nazari
S. pyri (larva)	1,070–5,800 (rises throughout larval life)	—	Florkin ('35b)
S. carpini (pupa)	—	21,000	Nazari
Prodenia eridania (larva)	1,044	1,469	Babers ('38)
Coleoptera:			
Several species	2,700–4,120	—	Florkin ('35b)
Hydrophilus piceus	3,400	7,000–8,800	Nazari, Florkin ('37a)
Dytiscus marginalis	—	8,400	Nazari
Hymenoptera:			
Apis mellifica (larvae and pupa)	6,656.25	1,812.5	Bishop, Briggs, and Ronzoni ('25)
Bombus agrorum	5,000–7,000	—	Florkin ('37c)
Orthoptera:			
Dixippus morosus	1,030 (lowest value in insects)	—	Florkin ('36a, '37c)
Arachnida:			
Black widow spider (plasma)	3,000–5,000 (entirely haemocyanin)	—	Boyd ('37)
Limulus polyphemus (plasma)	2,500 (practically entirely haemocyanin)	—	Dailey, Fremont-Smith, and Carroll ('31)
Decapoda:			
Maia squinado	681–5,081	10±	Delaunay ('13, '13a, '13b, '27)
M. squinado	5,156	—	Pora ('36)
M. squinado	2,840–3,570	—	Baglioni ('06)
Cancer pagurus	5,669	41.87	Pora
Palinurus vulgaris	—	50	Delaunay
Cancer productus, *C. antennarius*	2,125	—	Myers ('20)

TABLE 4—*Concluded*

ARTHROPOD (ADULT UNLESS OTHERWISE SPECIFIED)	PROTEIN	FREE AMINO ACIDS	INVESTIGATORS
Decapoda:—*Concluded*			
Carcinus maenas	4,000–4,200	—	Drilhon-Courtois ('34)
Astacus fluviatilis	5,668.7	41.9	Delaunay
A. fluviatilis	4,300	4.0 (only analyzed for tyrosin)	Pinhey ('30), Drilhon-Courtois ('34)
Telphusa fluviatilis	1,200–3,800	—	Drilhon-Courtois
Pollicipes cornucopia (cirrepede crustacean)	200	—	Florkin and Blum ('34)

in the blood of crustaceans, cephalopods, and gasteropods was first noted by Harless (1846). In 1878, Fredericq concluded that the serum, but not the coagulum, of octopus blood contains a body which, when acted on by acids, splits up into a protein residue with no heavy metal and a substance containing copper. This body, which he found would reversibly turn blue on exposure to the air, he termed haemocyanin. Richet (1879) made the first quantitative measurement of the O_2 capacity of the blood of a haemocyanin-containing animal (a shrimp) but did not specifically hint the presence of an oxygen transporter. The presence of haemocyanin in the blood of Crustacea was established by Krukenberg (1880, 1880a, 1882). Pantin and Hogben ('25) and Hogben and Pinhey ('26, '27) have described a colorimetric method for studying the dissociation of haemocyanin which is suitable for classwork; and Osterhout ('18) has suggested the use of the aerated blood of *Limulus* as an indicator for measuring the relative rate of oxygen consumption of organisms. The occurrence of carotinoid pigments in the blood of several species often masks the blue of oxyhaemocyanin. Thus, the blood of the crab, *Maia verrucosa*, is red when first shed but changes to a deep bluish green when shaken with O_2.

While the haemocyanin in the blood of a snail (Pantin and Hogben) is chiefly in the oxy-form that in the blood of intact Crustacea (Pantin and Hogben) and of *Limulus* is almost entirely in the unoxygenated condition. In fact, the oxygen concentration of the blood in the pericardial sinus of *Limulus* (Maluf, '37d) is even less than that of sea water of the same tonicity (see also Winterstein, '09, for *Maia*). The reason, however, that the gills of *Limulus* show no blue tinge is undoubtedly because the blood is in too thin a layer. In 1867, Paul Bert (cf. Redfield, '34) observed the change in color of the blood of cephalopod molluscs as it passed through the gills.

(ii) Distribution of haemocyanin and the respiratory function of the blood of arthropods in general. Haemocyanin occurs in the blood of various molluscs and, among arthropods, in the blood of certain decapod, notostracan, stomatopod, and amphipod Crustacea (cf. Redfield, '33; Florkin, '34), in *Limulus*, in spiders such as *Chaetopelma olivacea* (Wilson, '01; cf. Redfield, '34) and the black widow, *Latrodectus* (Boyd, '37), and in scorpions (Lankester, 1871; Svedberg and Hedenius, '33). It has been suggested that insects (Muttkowski, '21a, b) contain haemocyanin in their blood because the blood of crayfish, believed to contain haemocyanin and grasshoppers seemed to show Cu in approximately equal concentrations. No quantitative studies were, however,

made. "We have measured the concentration of copper in the blood of the Florida grasshopper and have found quantities so small that if it is present as haemocyanin the latter can have no importance in the transport of oxygen in the blood" (Redfield, '34). Babers ('38) has found that the total [Cu] in the blood of *Prodenia* larvae is only about 5 per cent and that that in the protein precipitate is as low as 1.99 per cent. From what has been said concerning the concentration of oxygen in the circulating blood it is evident that the haemocyanin in the blood of *Limulus* and *Maia* serves no significant respiratory function—at least under ordinary oxygen pressures. It is probable that haemocyanin, almost the only protein in *Limulus* blood plasma (Alsberg and Clark, '15; Montgomery, '30), in decapod serum (Halliburton, 1885), and in spider serum (Boyd, '37), acts mainly as a pH buffer. This is corroborated by the O_2 consumption—O_2 pressure curve of *Limulus*, which resembles that of the starfish, an animal with no oxygen transporter in its perivisceral fluid (Maluf, '37d).

Melvin ('31) analyzed the Cu content of whole insects and found that some insects accumulate Cu but all the information he gives us of the Cu content of the blood is that it is less than in certain tissues and waste products, i.e. less than 3.3 mgm./100 cc. Millot ('26) could detect no respiratory protein in the blood of certain spiders. Muttkowski nevertheless insisted that the blood of *Aeschna* (dragonfly) and *Dytiscus* (beetle) larvae must have some respiratory function since their blood reacted copiously with pyrogallol even after the animals had been under practically anaerobic conditions. But Bishop ('23) found that the oxygen *capacity* of the blood of honeybee larvae ranges between 0.2 and 0.8 vol. per cent, which he considers to be within experimental error of the amount that can be freely dissolved at ordinary temperatures. The oxygen concentration of the blood of beetles and fly larvae (Barratt and Arnold, '11; Florkin, '34, '37a, d), collected under paraffin without exposure to air, is, in the words of the former, "too small to determine," and with the modern Van Slyke technique used by the latter, occurs only in traces (0.0–0.1 vol. per cent). Similarly, Babers (38) has not been able to detect any O_2-combining power in the blood of the larva of the moth, *Prodenia*.

Astoundingly high figures for the oxygen concentration of the blood of decapod Crustacea and an insect have been given by Griffiths (1892). Thus the [O_2] of the blood of the crab, *Cancer pagurus*, was found to be about 14.8 vols. per cent; that of the crawfish, *Palinurus vulgaris*, about 14.5 vols. per cent (close to the older value of Richet, 1879); that of the lobster, *Homarus vulgaris*, about 14.8 vols. per cent, and that of the moth, *Acherontia atropos*, about 16.5 vols. per cent. According to Griffiths, therefore, the [O_2] of the blood of the moth is within the range of variation of the O_2 capacity of the haemoglobin-containing blood of mammals. Dhéré ('00, '03), Winterstein ('09), and Florkin ('37a, d) have shown that Griffiths' values are many times too high. Thus the O_2 capacity of the blood of haemocyanin-containing crabs and the lobster was about 1.4 vols. per cent. The O_2 capacity of the blood of *Limulus* (Redfield, Coolodge, and Hurd, '26; Alsberg and Clark, '14) varies considerably (0.43 to 2.14 vols. per cent), being, like the haemocyanin concentration, lower during starvation. The [O_2] of sea water at 25°C. and ordinary atmospheric pressure is *ca.* 0.50 vol. per cent.

(iii) Constitution. In all species examined (cf. Redfield, '34; Roche, '36) one

molecule of oxygen combines with a quantity of haemocyanin containing exactly 2 atoms of Cu. Within limits, the O_2 capacity of the blood varies directly with its Cu concentration (Dhéré, '03). Copper is the only heavy metal in haemocyanin since the evidence for zinc in *Limulus* haemocyanin is very probably due to impurities in the analytic vessels (Gatterer and Philippi, '33).

"Unpublished experiments made by Dr. Beecher . . . were also unsuccessful in demonstrating the presence of zinc in purified *Busycon* haemocyanin although this element could be detected in the whole blood . . . Conant, Dersch, and Mydans (personal communication) . . . suggest that the prosthetic group of *Limulus* haemocyanin is a complex copper salt of an unknown sulfur compound and a polypeptid consisting of one molecule each of leucine and tyrosine and three of serine" (Redfield *loc. cit.*).

Philippi ('19), however, noted an intense pyrrol reaction in *Helix* haemocyanin. For further data concerning the properties of haemocyanin the reviews of Dhéré ('28), Redfield ('34), Florkin ('34b), and Roche ('36), should be consulted.

The phylogenetic significance and apparent interrelationship of chlorophyll, haemoglobin, and haemocyanin are often considered to revolve around the essential pyrrol nucleus of the earlier pigment, chlorophyll (see, for instance, Moseley, 1877, and Gortner, '29).

The molecular weights of the haemocyanins are extraordinarily high. The molecular weight of *Limulus* haemocyanin is 1,300,000; of *Homarus americanus* is 640,000 (Svedberg in personal communication to Redfield, '34); of *Palinurus* is 446,000; of *Nephrops* is 820,000 (Eriksson-Quensel and Svedberg, '36; Svedberg, '37).

While the oxygen in haemoglobin is liberated by $K_3Fe(CN)_6$ (Barcroft, '14) and not by KCN (cf. Abderhalden, '11); that in haemocyanin is liberated by KCN (Kobert, '03; Redfield, Coolidge and Hurd, '26; Pearson, '36) and not by $K_3Fe(CN)_6$ (Stedman and Stedman, '25); that in hemerythrin is liberated by both (Marrian, '27; Cook, '27–'28); and that in echinochrome by $K_3Fe(CN)_6$ but not by KCN (Cook, *loc. cit.*). The oxygen can, however, be easily liberated from haemocyanin by a vacuum, such as that created in the Van Slyke-Neill manometer.

The percentage dissociation—oxygen tension curve of oxyhaemocyanin into haemocyanin and molecular oxygen varies with various factors such as pH (Pantin and Hogben, '25; Hogben, '26; Stedman and Stedman, '26), temperature, salts, and the variety of haemocyanin. The affinity for O_2 varies inversely with temperature (Pantin and Hogben, '25; Hogben, '26; Redfield, Coolidge, and Hurd, '26) and thus a given animal will be more active but more susceptible to oxygen lack at a higher temperature (within limits) than at a lower. Since haemoglobin acts in the same way, the same applies to poikilothermic vertebrates. Similarly, since the haemocyanin of *Limulus* blood is relatively more saturated at low oxygen tensions than that of several other animals (e.g. the squid, *Loligo*) under identical conditions (Redfield, Coolidge, and Hurd, '26), the activity of *Limulus* is quite limited at low oxygen pressures while the activity of *Loligo* is maintained for a brief period at the expense of molecular oxygen, released by the rapidly dissociating haemocyanin, until asphyxiation results. For reasons already noted above, however, it is hardly likely that haemocyanin is of any marked significance in the respiratory exchange of *Limulus*.

Contrary to haemoglobin, the affinity of *Limulus* Hcy for CO is only 1/20 as great as for O_2 (Root, '34). Animals possessing Hcy as their respiratory protein would, from this alone, be expected to be

less susceptible to CO-poisoning than those which depend upon Hb for their oxygen supply.

(b) Haemoglobin. (i) Distribution. Svedberg and Eriksson-Quensel ('33) have pointed out that while "the red respiratory pigment of invertebrates closely resembles that of vertebrates with regard to its absorption spectrum and O_2-binding capacity (Barcroft, '24), these two properties are connected with the hemin group and not with the protein molecule." They remarked (see also Svedberg and Hedenius, '33, '33a, '34; Svedberg and Eriksson-Quensel, '34) that, like haemocyanin and chlorocruorin, the red respiratory pigment which occurs in invertebrates has, in most of the few cases studied, a molecular weight of the order of millions while all other proteins have proteins with molecular weights of a lower magnitude (35,000–200,000). They therefore suggested the use of the term erythrocruorin for the entire red series, reserving the name haemoglobin for the variety which has a molecular weight of *ca.* 69,000, an isoelectric point at pH 6.7, and which is characteristic for the vertebrates with the exception of the Cyclostomata. Erythrocruorin indeed has priority.

"Now in the article of 1868 where Ray Lankester proposed the term chlorocruorin for the green blood pigment of the polychaete worms he suggested the term erythrocruorin for the red blood pigment of the invertebrates. In England the name cruorin at that time stood for respiratory blood pigment in general (suggested by Stokes 1864). In his next paper Ray Lankester (1870), however, abandoned the term erythrocruorin and called the red blood pigments of the invertebrates hemoglobin, the latter name, suggested by Hoppe-Seyler in 1864, having in the meantime come into general use for the blood pigment of the invertebrates."

Until the protein moiety of the red respiratory pigment of invertebrates is shown to be other than a globin and in view of the undesirability of nurturing a surplus of names in science, it appears that the term haemoglobin should be retained for the general group more especially since the molecular weight of the haemoglobin of the midge, *Chironomus plumosus* (Svedberg and Eriksson-Quensel, '34), is only *ca.* 31,400. That of *Daphnia* (Svedberg and Eriksson-Quensel, '34) is *ca.* 410,000. These are the only arthropods studied in this respect. The molecular weight of *Chironomus* haemoglobin is, within the limits of error, equal to a haemoglobin unit (= 34,500). If one believes that globins are characterised by a high histidin content (7 to 8 per cent) and by a deficiency in arginin (ca. 4 per cent) one might, in fairness to the term "etythrocruorin," state that this pigment, where it has been analysed in invertebrates (*Lumbricus*, *Arenicola*, *Glycera*), has, according to Roche ('36), a high arginin content (ca. 10 per cent) and a deficient histidin content (ca. 4.5 per cent). But what about *Chironomus*?

Haemocyanin never occurs in corpuscles, always being suspended in the blood. The same applies to haemoglobin where it occurs in arthropod blood. In 1861, Rollet isolated haematin crystals from "red-colored larvae," living in rain-water swamps, and identified the red substance as haemoglobin. This is the first record of haemoglobin in arthropods. Within this group haemoglobin occurs in the blood of certain entomostracans (*Apus*, *Branchipus*, *Artemia*, *Daphnia*, *Chirocephalus*, *Lernanthropus*, *Clavella*, *Congericola*), in larvae of certain species of the midge, *Chironomus*, and culicoid Diptera (Lankester, 1868, '69, '70, '71, '72; Heider, 1879; van Beneden, 1880; Regnard and Blanchard, 1883, '83a; Harnisch, '25; Muttkowski, '21b; Verne, '23). For the further distribution of oxygen transporters in the blood of animals and for phylogenetic discussions the excellent works of

Sorby (1876), Barcroft ('25), Redfield ('33), Florkin ('34a, b), and Roche ('36) should be consulted.

In 1902, Vaney first demonstrated that the red material of the fat-body and "tracheal body" of larvae of the oestrid fly, *Gastrophilus equi* is haemoglobin. This was later confirmed by von Kemnitz ('16) who found that its haemoglobin differs in its absorption bands from that of the horse (in which the larva is an endoparasite) and thus concluded that the larvae synthesize their own haemoglobin. The haemoglobin of each species is characteristic; this would be expected when it is realized that proteins are species-specific.

(*ii*) *Formation.* Protohaematin, a precursor of haematin, and globins are found in the cells of all aerobic organisms (Keilin, '33). The arthropods containing haemoglobin dwell in the midst of decaying organic matter, where the oxygen pressure is necessarily low. Newly hatched larvae of *Chironomus gregarius* (Pause, '18) have a colorless haemolymph. Under natural conditions, the blood begins to turn red during the middle of the third instar. When the larvae are kept in oxygen-saturated water, however, haemoglobin appears later in larval life. It is evident that the oxygen pressure in the water has an influence on the time of haemoglobin formation in these larvae.

It is known that chlorophyll and iron favors the formation of haemoglobin in mammals. Comas ('27) found that chironomid larvae will produce an ample amount of haemoglobin even when bred to a length of one cm. without food or when fed on mushrooms and potatoes. Green algae and green leaves taken as food enhanced haemoglobin formation as compared with those fed on the comparatively iron-free diet. It is, however, impossible to conclude from this work that the larvae can synthesize the tetrapyrrol nucleus of haemoglobin, for, there may exist a reserve of such in the egg. Furthermore, Verne ('23), by a similar technique, demonstrated that *Daphnia pulex* cannot synthesize haematin. While red pigment always appeared, it was, in the tests, exclusively the carotinoid, zooerythrin.

(*iii*) *Function.* Certain biologists, such as Miall (1898) and Pause ('18) have entertained the belief that, because haemoglobin-containing invertebrates live in oxygen-poor surroundings, their haemoglobin can store oxygen. In Krogh's laboratory Leitch ('16) showed that, as in vertebrates, the haemoglobin of *Chironomus* can act as a transporter but not as a store of oxygen. This is also true for other invertebrates possessing haemoglobin (Borden, '30–'31). In this respect it is significant that the haemoglobin of these animals releases its oxygen only at very low oxygen pressures (Leitch; Borden; Harnisch, '27, '36). Cole ('21) observed that *Chironomus* larvae live at the bottom of lakes which had been "shown," by Winkler's method, to contain no dissolved oxygen. Eggleton ('31), however, found that *Chironomus* larvae cannot live in water which had been deoxygenated by shaking with mud. Furthermore, *Chironomus* undergoes an O_2 debt during O_2 lack (Harnisch, '36). Since animals cannot store oxygen to any significant extent, it is necessary to reanalyze this water for oxygen by a more refined technique before supposing that the animals are capable of a true anaerobic metabolism (cf. Barcroft '34). *Chironomus gregarius* (Pause, *loc. cit.*) becomes photonegative and retires to the bottom coincidently with the appearance of haemoglobin. Species of *Chironomus* which do not contain haemoglobin (e.g. *C. motitator*) remain at the surface where there is more free oxygen (Miall).

(*c*) *Toxoproteins.* This is an arbitrary

group which, if taken in its broadest sense includes almost all proteins. The most potent poisons known are proteins. Thus, ricin from the castor bean is many times more toxic than HCN and has a great agglutinating and haemolyzing capacity. The bushmen of the Kalahari make arrow poison from water extracts of the larvae of *Diamphidia locusta* (Boehm, '23), the poisonous principle being a protein.

Several species of Orthoptera, Hemiptera, Coleoptera, Lepidoptera, and Hymenoptera (Cuénot, 1890; Lutz, 1895; Hollande, '11a, b, and '26; Rabaud, '22; Hingston, '27) eject blood, when touched suddenly. The blood emerges from a rupture in the cuticle. The fluid may be ejected to a distance of as much as two inches, as in certain Indian grasshopper larvae (Hingston), or merely form a drop on the surface of the insect, as in most cases. Certain skeletal muscles, especially those of the abdomen, contract and thus increase the blood pressure (Hollande, '26). The integument may rupture at points of least resistance, at certain pores, or at eversible vesicles, depending upon the species. This reflex bleeding, or so-called "autohaemorrhage," is of adaptive significance since insects smeared with the blood of blood-ejecting species become repugnant to their would-be predators (Lutz, 1895; Cuénot, 1896; Hollande, '11b; Rabaud, '22).

Hollande ('11b) has, however, pointed out that it is unnecessary to conclude that the emission of blood is a protection against *all* predators. Thus, the blood of the lepidopteron, *Leucoma salicis*, is, when injected, harmless to swallows and bats but deadly to lizards and frogs; that of coccinellid beetles is deadly to spiders, lizards, and sparrows but harmless to warblers. Furthermore, blood toxicity does not necessarily imply the possession of the capacity of reflex bleeding, for, the blood of the crabs, *Maia squinado* and *Eupagurus prideauxii* (Cantacuzène, '11, '20), haemolyzes and agglutinates vertebrate erythrocytes. There are no apparent histological differences between the blood of blood-ejecting species and their relatives which do not emit blood (Hollande, '11a).

(*d*) *Antibodies*. The blood of the crab, *Carcinus maenas* (Lévy, '24), parasitized with the rhizocephalid crustacean, *Sacculina carcini* gives an accentuated precipitate with dilute alkali. The unparasitized crabs yield a lesser precipitate. *Eupagurus prideauxii*, which lives symbiotically on *Adamsia palliata* (Cantacuzène and Damboviceanu, '34), is the only decapod crustacean the serum of which is capable of forming a precipitate with the toxin of *A. palliata*. Glaser ('18) immunized a grasshopper, *Melanoplus femur-rubrum*, against *Bacillus poncei* (pathogenic to grasshoppers). The blood of the immunized insects soon caused an agglutination of the bacilli in large masses. "I never saw a better reaction with *Bacillus typhosus* and typhoid serum." Insects have a remarkable natural immunity towards most bacteria even though these may be pathogenic to warm-blooded animals. There are, however, a number of bacteria which are harmless to warm-blooded animals but extremely pathogenic to insects. Artificial immunity can, however, be acquired (Chorine, '31).

(*e*) *Enzymes*. (*i*) *Tyrosinase*. The blood of many arthropods, such as decapod Crustacea (Hardy, 1892; Pinhey, '30), the phasmid *Dixippus* (Toumanoff, '26), various Lepidoptera (Geyer, '13; Glaser, '18; Heller and Moklowska, '30), beetles (Barratt and Arnold, '11; Gortner, '11; Werner, '26; Schmalfuss and Barthmeyer, '30), silkmoths at all stages (Yamafugi, '33b), and oestrid flies (von Kemnitz) turns dark brown when exposed to the air and thus exhibits the presence

of tyrosinase and the benzol-ringed chromogen. On the other hand, the blood of cicadas (Gortner), of the moths *Malacosoma neustria* and *Lymantria monacha* (Geyer), and of certain spiders (Millot, '26) contains no tyrosinase. There is a sexual difference in the blood of silkworm larvae and pupae, that of the males darkening more rapidly upon exposure to the air (Geyer).

Toumanoff (*loc. cit.*) concluded that the tyrosinase of *Dixippus* is liberated into the blood after the completion of development since all the internal organs yielded negative results. Such a hypothesis is unnecessary especially since Hardy (1892) seems to have demonstrated that tyrosinase is not freely suspended in the blood of the crayfish but is liberated into such when the corpuscles burst, as when the blood comes into contact with the air. These corpuscles are not present in the blood of *Limulus* and arachnids (Pinhey, '30) and the blood of such does not darken even upon the addition of tyrosine. Schmalfuss and Barthmeyer, working with insects, considered that the darkening is due to a loss of CO_2 and thus to an increased alkalinity, which favors the activity of tyrosinase. This does not take into account the fact that the blood of marine arthropods is alkalin. Barratt and Arnold wrote that "since the blood [of insects] darkened on exposure to air, or rather to oxygen, it follows that it contained exceedingly little dissolved oxygen in the straw-yellow condition which it exhibited in the living body." This, too, does not take into consideration the fact that the circulating blood of many crustaceans has oxygen in appreciable quantities—almost as much as in sea water (see above). Parenthetically, it may be stated that the optimum temperature and pH for the activity of tyrosinase of *Bombyx* blood (Yamafugi, '33) is pH 6.6 and 37°C.

(*ii*) *Other oxidases.* The blood of various insects contains peroxidase (Muttkowski, '21a; von Kemnitz, '16), and catalase (von Kemnitz; Yamafugi, '33b); that of spiders has no catalase (Millot, '26). The blood of silkmoths contains phenolase, peroxidase, and catalase (Yamafugi, '33b, '34; Yamafugi and Goto, '36).

(*iii*) *Hydrolyzing enzymes.* Various species of lepidopterous larvae contain amylase, maltase, proteinase but no lactase, cellulase, or lipase in their blood (Dirks, '22). Amylase occurs in the blood of honeybee larvae but not in the salivary glands or gut of the same (Bishop, '23; Bertholf, '27). The blood of larvae of the fly, *Gastrophilus* (von Kemnitz), has lipase, very active amylase and proteinase; that of the crab, *Maia*, and the lobster, *Homarus*, digests starch, sucrose, fat, and fibrin (Heim, 1892; Sellier, '02, '04); that of silkmoths (Yamafugi, '33a; '34a, b, c) has lipase, proteinase, amylase, sucrase, and maltase. Such enzymes are probably of paramount importance during metamorphosis when they would act on fats, glycogen, and proteins discharged into the blood by the disintegrating tissues and fat-body. In this connection, it is noteworthy that the activity of all the known blood enzymes of the silkmoth (Yamafugi), except catalase and lipase, is greatest at the beginning of metamorphosis, declines during pupal life, and rises in the adult. The proteinases are probably also of importance in the synthesis of blood proteins.

(5) *Carotinoids and carotinoproteins*

These pigments are transported by the blood and impregnate the hypodermal cells of many arthropods (Herrick, 1895; Keeble and Gamble, '04; Grandmougin, '12; Verne, '20a, '20b, '21, '23; Palmer and Knight, '24; Lwoff, '27; Abeloos and Toumanoff, '26; Toumanoff, '28; Fabre

and Lederer, '33; Brown, '34). The various bluish to reddish pigments of undescribed constitution noted in the blood of arthropods (Lund and Schulz, '30; von Siebold, 1848; Grube, 1859; Klunzinger, 1864; Gerstaecker, 1879; Heider, 1879; de Mierzejewski, 1882; Cuénot, 1891, 1894; Müller, 1894; Gruvel, 1894; Dawson, '34) are chiefly "lipochromes," i.e. carotinoids or carotinoproteins (Jolyet and Regnard, 1877; Fredericq, 1879; Newbigin, 1879; Krukenberg, 1880–2; MacMunn, 1883, 1883a; Halliburton, 1885, 1885a; Palmer and Knight, '24; Jucci, '30). The yellow carotinoid (xanthophyll) of the blood of silkworms is derived from the food and forms the yellow color of the cocoon, being absorbed by the silk glands (cf. Maluf, '38b). No animal has as yet been ascertained to be capable of synthesizing a carotinoid compound. The blood of insects (Muttkowski, '23) may be colorless (e.g. *Calliphora*), yellowish (e.g. *Hydrophilus*), orange (e.g. *Leptinotarsa* larvae), orange-red to red (e.g. certain ephemerids), bluish (e.g. *Pro-*

TABLE 5

Nitrogenous products of protein degradation

(Mgm./100 cc.)

ARTHROPOD	UREA	PURINES (TOTAL)	URIC ACID	CREATININ	NH_3	UREA + NH_3	OTHER NON-PROTEIN N	INVESTIGATORS
Insects:								
Honeybee (larva)	—	—	5.3	1.1	—	traces	41.6	Bishop, Briggs, and Ronzoni ('25)
Hydrophilus piceus	7.4	—	8–15	—	—	—	—	Florkin ('37a)
Bombyx mori (larva)	—	—	10–14	—	—	—	—	Jucci and Deiana ('30), Florkin ('37a)
Prodenia eridania (larva)	6.2		14.8	8.0	—	—	—	Babers ('38)
Deilephila euphorbiae (larva)	20	—	—	—	—	—	—	Heller and Moklowska ('30)
Dixippus morosus	—	—	10.4	—	—	—	—	Florkin ('37c)
Dytiscus (carnivorous)	—	—	17.97	—	—	—	—	Florkin ('37c)
Several arthropods (names not stated)	—	—	—	none	—	—	—	Morgulis ('23)
Decapods:								
Palinurus vulgaris	6.56	—	—	—	—	—	—	Sanzo ('07)
P. argus	12–22	—	0.9–6.0	none	—	—	9–17	Sanzo
P. vulgaris	3.38	0.30	0.24	—	0.88	2.68	6.0	Delaunay ('13, '13a, '13b, '27)
Cancer productus, *C. antennarius*	5.15	—	4.7	0.78	1.15	6.3	—	Myers ('20)
Maia squinado	2.90	3.6	0.18	—	1.74	4.64	5.06	Delaunay
M. squinado	—	—	10.95	—	—	—	—	Boivin ('29)
M. squinado	3.83	—	—	—	—	—	—	Sanzo
Cancer pagurus, *Astacus fluviatilis*	1.8	0.30	0.24	—	0.88	2.68	6.0	Delaunay
Portunus corrugatus	3.68	—	—	—	—	—	—	Sanzo

tenthus larvae—Diptera), blue-green and green (e.g. *Anax* and *Aeschna* larvae); that of the Tardigrada (Shipley, '09) and Pycnogonida (Thompson, '09) is colorless.

(6) *Nitrogenous wastes*

Non-volatile nitrogenous wastes (Table 5) must be transported by the blood to the excretory organs in order to be eliminated. In the terrestrial forms, such as the insects, mites, and ticks, the bulk of the nitrogenous wastes is excreted in the form of uric acid which probably exists in the blood in the form of neutral dibasic urates. The carnivorous insects apparently have a higher [uric acid] in their blood than the herbivorous insects. The blood of Crustacea contains considerable quantities of urea. This is found only in traces in the blood of insects, with the possible exception of the moth, *Deilephila euphorbiae*. Approximately half or more of the non-protein nitrogen in the blood of arthropods is of unknown constitution and may probably be in the form of trimethylamine. Both Myers, in crabs, and Bishop, Briggs, and Ronzoni, in the honeybee larva, have found the creatinin concentration of the blood (Jaffé reaction) to approximate that of man. This is remarkable since, in the former, the hydrolysis of phosphoarginin seems to take the place of phosphocreatin during muscular contraction even though Meyerhof ('28) found phosphoarginin and phosphocreatin in approximately equal amounts in muscles of the crayfish. Morgulis nevertheless wrote that "it can be stated definitely with the support of an extensive number of analyses that creatinin is never present in the blood of arthropods." He did not, however, specify which arthropods. The creatin concentration of the blood of honeybee larvae is 2.0 mgm. (Bishop, Briggs, and Ronzoni) and that of *Cancer* is 0.58 mg. (Myers), both values being somewhat less than the range in man (= *ca.* 3–7 mgm. per 100 cc.).

(7) *Alkaloids*

When the larvae of the butterfly, *Tortrix viridana* (Hollande, '23), feed on leaves of the oak, *Quercus sessiliflora*, epithelial cells of the mid-gut become replete with alkaloidal (probably tannin) crystals in their vacuoles. In rare cases their blood yields a positive reaction for alkaloids.

SUMMARY

1. The blood cells are involved in phagocytosis and clotting.

2. Clotting among arthropods often involves protein coagulation and an agglutination of blood cells. Both processes are possibly independent of each other. In many species the blood does not clot at all.

3. Clotting in most arthropods is probably evoked by a liberation of thrombin into the haemolymph as a consequence of the rupture of certain blood cells.

4. The blood of terrestrial arthropods is generally on the acid side of neutrality while that of certain marine arthropods (decapods) is known to be on the alkalin side of neutrality.

5. The acid-base balance is regulated by blood carbonates, phosphates, proteins, amino acids, the excretory organs, carbonic anhydrase (?), and, in fairly sized atracheate forms, to a slight extent by haemocyanin.

6. Most of the osmotic pressure of the blood of Crustacea and *Limulus* is accounted for by the [mineral] of the blood. In insects (terrestrial forms) the amino acids form the greatest component of the osmotic pressure of the blood. The concentration of amino acids in the blood of insects is extraordinarily great.

7. The osmotic pressure of the blood of most freshwater and terrestrial species is

lower than that of marine forms and approximates that of mammals.

8. Arthropods, in postembryonic stages, can invade fresh water if their integument is wholly impermeable to salts from interior to exterior and, in forms in which a portion of the integument is permeable to water (e.g. the gill filaments of crayfish and *Aedes* mosquito larvae), if excretion of a copious and very hypotonic urine occurs. The inevitable loss of salts with the hypotonic urine may be replenished by the ingestion of salts with the food or by the secretion, by the skin, of salts from the external hypotonic medium into the blood against an osmotic force.

9. Arthropods, such as certain mosquito larvae, which can breed just as well in fresh water as in strong brine, can do so possibly by virtue of an integument that is impermeable to water and salts in both directions.

10. The decrease in the blood π of certain marine decapods, which follows the rise (of unknown origin) of this just prior to molting, can be explained solely on a dilution basis. The intake of water aids ecdysis and the expansion of the new integument.

11. With respect to their condition in hypotonic media, marine arthropods exhibit graded differences depending upon the extent of the permeability of their integument and their capacity to secrete salts from the exterior into their blood.

12. The osmotic effects of drying are the same as those of hypertonic media.

13. The blood of most marine Crustacea is more or less isotonic with the external medium but the proportions of the various minerals are not the same in both media. This is, in part at least, due to selective secretion of minerals by the kidneys.

14. The blood of insects is relatively poor in minerals and the latter deviate greatly, in their relative concentrations, from the condition in sea water.

15. As far as the evidence goes, the blood of arthropods with a well developed tracheal system contains no respiratory protein or other oxygen-combining substance.

16. Like haemocyanin, haemoglobin, where it occurs among arthropods, never exists in corpuscles but is always freely suspended in the haemolymph.

17. The haemoglobin is of no practical oxygen-storage significance but, since it dissociates only at very low oxygen pressures, is of importance in oxygen-poor media.

18. Certain insects eject blood over themselves which contains toxoproteins, thus protecting themselves against certain predators.

19. The hydrolytic enzymes freely present in the blood are probably of importance during metamorphosis and in the manufacture of blood proteins, glycogen, and fats.

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ADOLESCENT STERILITY (*Concluded*)

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THE HUMAN SPECIES

SCHULTZ and Snyder (114) remarked in 1935 that "Conclusive evidence of adolescent sterility in man is difficult to obtain" (p. 198). This, unfortunately, is true, and it is for this reason, among others, that the present paper has been written, in the hope that those who enjoy the requisite opportunities may be persuaded to undertake the search for the "conclusive evidence." In what follows the evidence may be evaluated in terms of probability alone. "Conclusive evidence" is evidence to which so high a degree of probability attaches that there can be little or no doubt that it represents a true description of conditions. None of the evidence relating to the human species which is here examined possesses anything like so high a degree of probability that it may be taken as a perfectly true description of conditions. Exactly what the degree of probability here is the reader may have an opportunity of determining for himself.

Historically, the subject of adolescent sterility is not altogether without interest. In the writings of the great Hindu physician Suśruta, who flourished some five centuries before the Christian Era, there occurs the following remarkable passage: "If a man under twenty-five deposit his germ (*garbha*) in a woman younger than sixteen, it will (most likely) die in the womb. Even if it be born alive it will either soon die, or he will be imbecile and weakly so long as he lives" (125).

Plato not being either a physician or a biologist has nothing more pertinent to offer than the following passage, which occurs in *The Republic* (99):

> A woman . . . may begin to bear children to the State at twenty years of age, and continue to bear until forty; a man may begin at five-and-twenty, when he has passed the point of life at which the pulse of life beats quickest, and continue to beget children until he be fifty-five.
>
> Certainly . . . both in men and women those years are the prime of physical as well as of intellectual vigour.

In the *Politics* Aristotle (5) writes:

> "Since the legislator should begin by considering how the frames of the children whom he is rearing may be as good as possible, his first care will be about marriage—at what age should his citizens marry? . . . The union of male and female when too young is bad for the procreation of children; in all other animals the offspring of the young are small and ill-developed, and with a tendency to produce female children, and therefore also in man, as is proved by the fact that in those cities in which men and women are accustomed to marry young, the people are small and weak; in childbirth also younger women suffer more, and more of them die; some persons say that this was the meaning of the response once given to the Troezians—the oracle really meant that many died because they married too young; it had nothing to do with the ingathering of the harvest. It also conduces to temperance not to marry too soon; for women who marry early are apt to be wanton; and in men too the bodily frame is stunted if they marry while the seed is growing (for there is a time when the growth of the seed, also, ceases, or continues to but a slight extent). Women should marry when they are about

eighteen years of age, and men at seven and thirty; then they are in the prime of life."

Matthews Duncan (30) writing in 1866 suggested that: "In the case of some peoples, facts might be collected regarding wives so young as to be in a large proportion sterile from immaturity; and their fecundity gradually appearing as age advanced, might produce a column of mothers from ten to twenty years of age, showing a gradually increasing fecundity of the population at these ages" (p. 24).

Before turning to an examination of the evidence which Duncan himself presented in his great book, we may here note what, after a very careful search, proved to be the earliest discoverable recognition of the phenomenon of adolescent sterility in man. This is by Renauldin (105), and occurs in his article "Nubilité" in the great *Dictionaire des Sciences Médicales* of 1819.

Renauldin writes:

NUBILITY, *s. f.*, *nubilitas*, the aptitude for marriage.

Nubility is not to be confused with puberty; the latter has a slow or a rapid beginning and development which coincides with the last efforts of general growth: the former assumes this growth terminated and all the organs having reached the degree of perfection and power necessary to permit man to procreate his kind, and woman to bear the fatigues of pregnancy, childbirth and its aftermaths.

This is beautifully clear; yet in the same work Maygrier (74) writing on menstruation equates the first appearance of the latter with the capacity to procreate. It is not until more than a quarter of a century later that we obtain a statement concerning the phenomenon based on detailed observations which are carefully reported; this is by J. M. Waddy (132).

Waddy carried out his inquiries among the factory hands of the district of Birmingham in England, and the following are his observations on the "age at commencement of menstruation":

"Of 623 females, in one the catamenia occurred at nine years of age; 2 menstruated at ten; 15 at eleven; 46 at twelve; 87 at thirteen; 130 at fourteen 115 at fifteen; 105 at sixteen; 67 at seventeen; 43 at eighteen; 10 at nineteen; and two at twenty" (p. 674).

Waddy goes on to add that:

"Out of 628 females, we find marriage took place in upwards of 500 persons previous to the twenty-fourth year of their age. Yet few pregnancies took place before that period. The greatest number of pregnancies range from the twenty-fourth to the thirty-fourth year of age. The largest number of marriages are at the nineteenth and twentieth years; and yet only six individuals were pregnant at nineteen years old, and only twenty-seven at twenty. Surely these facts show that the powers of procreation are feeble in the female of tender years; and where Nature indicates a fact, we do well to attend to her instruction" (p. 675).

This is splendid for 1846.

In 1860 the French gynecologist Dubois (28) in discussing nubility writes as follows:

"When this aptitude is developed and when the genital functions may be exercised in woman, without probable prejudice to herself or to her offspring, she is considered nubile.

"Thus understood, nubility not only implies the abstract faculty of procreating, but the possibility of a procreation not injurious to the mother or to the infant.

"Nubility results from the necessary accomplishment of two orders of modifications: the one is local and is produced in the organs of generation, the other is general and affects the whole economy.

"The manifestation of the first, which is also the more important, has for its consequence, puberty, which it is necessary to take care not to confuse, as several authors have done, with nubility, of which it is only one of the essential conditions.

"I wish thus to give their true meaning to two expressions, too often employed as if they had the same signification. The word nubility implies the idea of an aptitude, puberty implies that of a condition which favours or renders possible the exercise of this aptitude. A girl to be nubile must first have puberty. But when she has puberty, it does not

follow that she is nubile, because puberty is not the only condition necessary for nubility. The ancients made no confusion in this matter. *Puberty*, from *pubes*, hair, indicated the age when certain parts began to be covered with hair. *Nubility*, from *nubis*, a cloud, veil and from its derivative, *nubilis*, indicated the age when the young girl was in a state to wear the nuptial veil, that is to say, to be married" (p. 269).

Our next observation relating to these matters is from the magnificent gynecological treatise written in 1867 by Joulin (64). Joulin writes:

"Nubility is the complement of puberty. These two states should not be confused; they rarely develop at the same time, and their appearance is ordinarily separated by an interval of several years. Puberty is the age at which the young girl becomes a woman; nubility is the period when she becomes capable of all the requirements of maternity. It is frequent, in our latitudes, to see the menses appearing at eleven or twelve years; pregnancy will strictly speaking be possible, but assuming that the young mother has escaped the dangers of a labour so difficult for her, will she be able to nourish her infant, and give it the necessary care? Is she capable of understanding the full extent of her duties and meeting all the difficulties? No, for nubility has not yet arrived, and it is then only that the complete development of the organs, of the bodily powers, and of the intelligence will permit her to fulfill this task adequately. The Civil Code authorises matrimonial union when the woman is fifteen years old and the man eighteen; but civil law is not in accordance with physiological law, and the race which permits such premature unions will not be long in degenerating. No general limit should be fixed, as is done, for nubility; were this limit fixed at 18, 20, or 22 years, numerous deviations from the common level would occur.

"When I am consulted as to the desirability of marriage for very young individuals, I customarily reply to the parents: that they should not permit their daughter to marry, that is to say, expose her to the risk of becoming a mother until a year at least has elapsed after her stature has ceased to increase. This is the period which I fix upon as nubility; embonpoint, size may add to the volume of organs, but Nature will add nothing to their development" (pp. 103–104).

A few months later, in 1866/67, we find Matthews Duncan (29) writing:

"It is, I believe, a common notion that the occurrence of menstruation indicates the arrival of the nubile age. Authors occasionally use such expressions as—advent of nubility and commencement of menstruation—as synonymous. The age of puberty may be contemporaneous with the age of nubility; but it cannot be assumed to be so without proof, for very little reflection will suggest to the physiologist many reasons for supposing that the marriageable age is generally delayed for several years after the arrival of the age of puberty" (pp. 207–214).

In corroboration of this point of view Duncan then quotes the passage from Joulin given above. He then goes on to discuss the dangers of early maternity, and quotes two breeders as saying

"that the mortality of the young of these animals [lambs and calves], when the mothers are immature, is much greater than when they are well grown. . . . One of them says, 'Taking the first lamb from ewes at one year old has in almost every case failed to be remunerative, owing to the frequent deaths of the lambs. The same may be said of young heifers though the mortality of the offspring may not be so marked as in that of sheep' " (p. 212–213).

"In conclusion, it is almost useless to add that I consider the age of about from 20 to 25 the nubile age of woman. The numerous facts and arguments I have adduced, appear to me to bear out distinctly this conclusion. Below 20 years of age, woman is immature, she runs considerable risk of proving sterile, and if she does bear a child she runs a comparatively high risk of dying in childbed; besides, her early marriage brings many other disadvantages. . . . The woman above 25 years of age is mature, but to counterbalance this, she encounters some greater risks than the very young wife's though of a similar nature" (p. 214).

In his book published in 1866 Duncan (30) reprinted the article from which these passages have been taken together with some additions as Part VIII (pp. 277 sqq.).

Duncan, who carried out most of his investigations during the fifties and sixties of the last century, has made available a large amount of data relating chiefly to Scottish women of the laboring classes, data of the greatest interest in our present

connexion. In Table 4, for example, the ability of women marrying at different ages to bear children within the first year of married life is clearly described.

From Table 4 it is evident that women of the 15–19 year group are less fecund within the first year of marriage than women of the presumed mature group of 20–24 years. In the 25–29 year group, the ability to conceive within the first year is already less than in the 15–19 year group, and steadily declines with age.

When the conditions for the first two years of marriage are considered these startling inequalities are for the most part removed, as is shown in Table 5.

What this tremendous increase in fecundity in the second year of marriage over the first year of marriage, reflected in Table 5, means it would be difficult to say and foolhardy to suggest here. What is of significance for us here is that in the second year of marriage six times as many women conceived within the 20–34 year

TABLE 4

*Initial fecundity of women of different ages within the first year of marriage**

AGES OF WIVES NEWLY MARRIED	15–19	20–24	25–29	30–34	35–39	40–44
Number of wives newly married	700	1,835	1,120	402	205	110
Wives-mothers within 1st year	96	339	139	46	19	4
Percentage of latter to former	13.71	18.48	12.41	11.44	9.27	3.63

* After Duncan, Tab. 9 (the complete table is not reproduced).

TABLE 5

*Initial fecundity of women of different ages within the first two years of marriage**

AGES OF WIVES NEWLY MARRIED	15–19	20–24	25–29	30–34	35–39	40–44
Number of wives newly married	700	1,835	1,120	402	205	110
Wives-mothers within 2 years of marriage	306	1,661	849	253	84	17
Percentage of latter to former	43.71	90.51	75.80	62.93	40.97	15.45
Increase in fecundity over the first year						
	30.00	72.03	63.39	51.49	31.70	11.82

* After Duncan, Tab. 10 (the complete table is not reproduced).

It must be clearly borne in mind that this table tells us no more than that *the ability to conceive within the first year of marriage* is greatest in the young mature group, less in the immature group, and increasingly smaller in the older groups. We may legitimately assume that this difference in first year fertility in the immature and older groups is due to different factors; in the immature group being due to incomplete sexual development, and in the older mature groups to factors which can at present only be guessed at.

groups as were able to conceive within the first year of marriage, and more than four times as many in the 35–44 year groups; whereas in the relatively immature 15–19 year group scarcely more than three times as many were able to conceive in the second year than in the first year of marriage. Thus, the relative infecundity of the 15–19 year group is here interestingly illustrated.

If now we examine the data for the women of under 20 years of age by means of annual instead of quadrennial incre-

ments we shall obtain a clearer view of the initial fecundity of these women during the first and second year of marriage.

From Table 6 we may gather that in the first year of marriage the Scottish women of 16 years of age investigated by Duncan were found to have become mothers in only 6.45 per cent of cases; at 17 years of age fecundity is increased by about one-fifth; at 18 years of age almost twice as much as at 17, and two-and-a-quarter times as much as at 16 years of age; and at 19 the increase over the preceding age is one-fourth again as great as marriage than those of the 18 and 19 year groups. Brides of all four groups showed in a marked degree an inability to conceive in the first year of marriage, though this inability was most marked in the youngest group, becoming increasingly less marked with the advance to the 19 year group. Thus, it is seen that the more mature groups exhibit a greater ability to overcome this initial infecundity than the younger groups.

It is perfectly legitimate to assume that the conditions of nutrition, occupation, climate, fertility of husbands, method of

TABLE 6

*Initial fecundity of women under 20 years of age in the 1st and 2nd years of marriage**

AGE OF WIVES NEWLY MARRIED	16	17	18	19
Number of wives newly married	43	108	225	314
Wives-mothers in 1st year of marriage	2	7	31	56
Corrected per cent**	6.45	7.77	14.70	18.30
Wives-mothers within two years of marriage	4	27	98	177
Corrected per cent**	12.90	30.00	46.44	57.84

* After Duncan, Tables 11 and 12 combined.

** Note: By corrected per cent is meant that a correction has been made to allow for the fact that some of the young brides may not yet have commenced menstruating at the time of marriage. This correction tends to lessen the contrast between the fecundity figures of say, the 16 and 20 year groups. It is possible that this correction was not necessary; it doesn't seem very likely that girls would marry had they not commenced menstruating. At least this would not be the case among Scottish girls, upon whom these figures are based.

at 18, and almost three times as great as at 16.

A similar lag in fecundity in the 16 year old women is noticeable in the second year of marriage, for whereas in the 17 year old brides fecundity has increased by four times over the first year of marriage, $3\frac{1}{7}$ times in the 18 year old group, and $3\frac{1}{2}$ times in the 19 year old group, the increase in the 16 year old group has only been twice as much.

From such evidence we conclude that the Scottish brides investigated by Duncan some eighty years ago at the ages of 16 and 17 years were significantly less able to conceive within the first year of intercourse, and contraception, were much the same in these several age groups; it would seem very unlikely from Duncan's account that any kind of contraception was ever practised. Hence, as far as they go, these data may be accepted as indicative of the fact that immature women, here arbitrarily placed in the 15–19 year group, are less frequently able to conceive than mature women, here arbitrarily placed in the 20–35 year group.

These conclusions are fully corroborated by the findings on Indian women reported in 1931 by Pillai (97) for the province of Travancore, and in 1939 by Pearl (96) for American Women.

Duncan's data would indicate that the maximum degree of fecundity is reached at 23 years, before which the capacity is in process of development, and continues until 27 years, whenafter it steadily declines.

Another table from Duncan on a different series of women may be cited here as of interest in our present connexion.

Table 7 illustrates once more, in a totally different series of women, the relative infertility of wives under 20 years of age as compared with the mature women.

Harris (48) made the following pertinent remarks in the same connexion in 1873:

> The *incipiency of menstruation* in our large cities, as a general rule, marks only the gradual approach of the nubile period, and occurs before there are very decided evidences of womanly development, especially in the maturity of the pelvic diameters; so that the possibility of conception is still quite remote. Pelvic expansion, which appears to have been general in cases of early pregnancy at any age, enabling the subjects of it to bring forth living children of full or nearly full size, is evidently only in its incipiency in a large number of young menstruous girls.

TABLE 7

*The variation in sterility according to the ages of wives in Providence**

AGES OF BRIDES	UNDER 20	20–25	25–30	30–40	40–50	TOTAL
Number	144	366	161	108	22	801
First children	49	215	113	45	2	424
Sterile	95	151	48	63	20	377
Per cent sterile	65.97	41.25	29.8	58.3	90.9	47.06

* After Duncan, Tab. 71 (2nd Ed. 1871, p. 201, 30b).

TABLE 8

*The interval between marriage and birth of first child in wives married at different ages**

MOTHER'S AGE AT MARRIAGE	15–19	20–24	25–29	30–34	35–39
Number of mothers	649	1905	809	251	96
Average interval from marriage to 1st childbirth (in mos.)	18.2	15.9	16.2	18.1	19.1

* After Duncan, Tab. 38 (condensed).

A final table from Duncan further illumines the points we have here been discussing.

Initial infecundity is, from Table 8, again seen to be overcome earlier in the mature groups from 20–34 than in the immature 15–19 year group. The relatively greater initial infecundity of the older group between 35 and 39 may be explained as due to factors quite different from those operating in the case of the immature group; in the latter case we must posit immaturity and all that that implies; in the former case, perhaps the beginning of an involutionary process.

> The *preparatory period*, which usually exists between the first appearance of the menses and the age of possible conception, varies from a few months to several years; but there have been instances in which impregnation followed the first menstrual epoch, or even took place before it has appeared. In tropical countries where young menstrual girls are given in marriage, impregnation very rarely takes place until some time has elapsed, thus marking the duration of this period of sexual preparation.

Mikulicz-Radecki and Kausch (78), in an investigation carried out in the Woman's Clinic of the University of Berlin, reported in 1935 that in 74 cases where first sexual intercourse occurred in postmenarchial girls between the ages of 13

TABLE 9

Changes in median pregnancy and live-birth rates (per 100 computed ovulations) with advancing age. Whites multiparae, married once only, living in wedlock, and free of gynecologic disease, married in age group 15–19 and thereafter continuously exposed to risk of conception through age period when observed. None made any contraceptive effort at any time

A. Median Rates

GROUP	N	MEDIAN RATES IN INDICATED AGE PERIODS				
		15–19	20–24	25–29	30–34	35–39
40 years old and over at observation:						
Pregnancy rates	63	2.25 ±0.59	6.83 ±0.37	4.78 ±0.37	4.43 ±0.44	4.17 ±0.56
Live-birth rates	63	2.08 ±0.57	4.90 ±0.37	4.56 ±0.30	4.31 ±0.37	4.03 ±0.46
35–39 years old at observation:						
Pregnancy rates	169	2.54 ±0.41	4.88 ±0.29	4.49 ±0.29	4.21 ±0.27	..
Live-birth rates	169	2.27 ±0.41	4.74 ±0.25	4.38 ±0.25	4.03 ±0.26	..
30–34 years old at observation:						
Pregnancy rates	242	2.75 ±0.40	4.68 ±0.23	4.42 ±0.21	..	..
Live-birth rates	242	2.33 ±0.39	4.54 ±0.23	4.20 ±0.21	..	..
25–29 years old at observation:						
Pregnancy rates	482	3.12 ±0.40	4.61 ±0.17	..	..	..
Live-birth rates	482	2.50 ±0.36	4.42 ±0.16	..	..	..
Weighted average, all ages at observation:						
Pregnancy rates	956	2.87	4.82	4.49	4.27	4.17
Live-birth rates	956	2.39	4.54	4.31	4.09	4.03

B. Standard Deviations of Rates

GROUP	N	STANDARD DEVIATIONS IN RATES AT INDICATED AGES				
		15–19	20–24	25–29	30–34	35–39
40 years old and over at observation:						
Pregnancy rates	63	5.56 ±0.33	3.47 ±0.21	3.47 ±0.21	4.13 ±0.25	5.28 ±0.32
Live-birth rates	63	5.39 ±0.32	3.48 ±0.21	2.79 ±0.16	3.45 ±0.21	4.30 ±0.26
35–39 years old at observation:						
Pregnancy rates	169	6.33 ±0.23	4.39 ±0.16	4.51 ±0.17	4.19 ±0.15	..
Live-birth rates	169	6.24 ±0.23	3.77 ±0.14	3.88 ±0.14	3.94 ±0.14	..
30–34 years old at observation:						
Pregnancy rates	242	7.38 ±0.23	4.32 ±0.13	3.86 ±0.12	..	..
Live-birth rates	242	7.25 ±0.22	4.18 ±0.13	3.80 ±0.12	..	..
25–29 years old at observation:						
Pregnancy rates	482	10.31 ±0.22	4.33 ±0.09	..	..	..
Live-birth rates	482	9.46 ±0.21	4.13 ±0.09	..	..	..
Weighted average, all ages at observation:						
Pregnancy rates	956	8.55	4.28	4.04	4.17	5.28
Live-birth rates	956	8.06	4.04	3.69	3.81	4.30

TABLE 9—*Concluded*

C. Mean and Median Ages at Marriage and at Observation of the Four Cohorts of Women dealt with Above

Cohort	Age at Marriage		Age at Observation	
	Mean	Median	Mean	Median
First cohort. Observed at 40 and over....	18.21 ±0.10	18.43 ±0.13	42.48 ±0.14	41.98 ±0.17
Second cohort. Observed at 35–39.....	17.92 ±0.07	18.04 ±0.08	37.67 ±0.06	37.68 ±0.08
Third cohort. Observed at 30–34.....	18.15 ±0.05	18.37 ±0.07	32.75 ±0.05	32.70 ±0.07
Fourth cohort. Observed at 25–29.....	18.15 ±0.04	18.39 ±0.05	27.74 ±0.04	27.70 ±0.05

and 17 years inclusive that only 23 conceived between these same ages, although in approximately 78 per cent of these cases no attempt at contraception had been made. These investigators believe that this low adolescent fertility is probably due to the fact that ovulation normally follows only some years after menarche. It would certainly appear reasonable to conclude that of the 69 per cent of postpubertal females who failed to conceive in this series failure was in the greater number of cases due to the fact that they were physiologically unprepared to do so.

Pearl (96) in an investigation, reported in 1939, relating to the fertility of 956 overtly fertile healthy American women who had been continuously exposed to sexual intercourse, found that fertility within the 15–19 year group was very significantly lower than in all the later age groups (from 25 to 39 years inclusive) investigated. These facts are well brought out in Table 9 and also in Fig. 1. Pearl comments upon these findings in the following words:

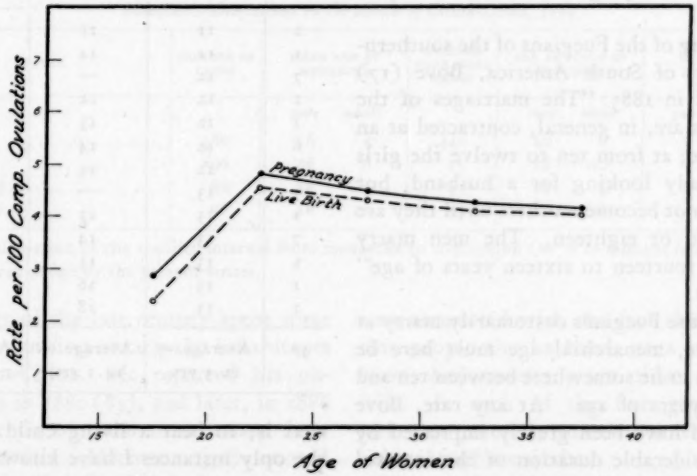

Fig. 1. Changes in the Unweighted Averages of Median Pregnancy and Live-Birth Rates with Advancing Age in Four Homogeneous Cohorts of Women in Whose Married Life no Contraceptive Efforts Were Made (Pearl, 1939)

"The low median fertility in the age period 15–19 . . . may be regarded as the

statistical expression of the biological fact, now well established, that in the human species there is a considerable time-lag after puberty before the complete expression of fertility becomes fully established, quite apart from the postponement of marriage" (p. 43).

Some evidence from the earlier anthropological literature may now be cited.

Reporting, in 1861, the observations of Schurmann, Protector of the natives of the Port Lincoln district of South Australia from 1840 to 1846, Wilhelmi (137) states that "Although they married so very young, (10 to 12 years), the women, according to Mr. Schurmann's observations, generally have no children before the age at which they get them in Europe" (p. 164).

Writing of the Fuegians of the southernmost tip of South America, Bove (17) observed in 1883: "The marriages of the Fuegians are, in general, contracted at an early age; at from ten to twelve the girls are already looking for a husband, but they do not become mothers until they are seventeen or eighteen. The men marry at from fourteen to sixteen years of age" (p. 158).

Since the Fuegians customarily marry at menarche, menarchial age must here be assumed to lie somewhere between ten and twelve years of age. At any rate, Bove seems to have been greatly impressed by the considerable duration of the interval which elapses between marriage and motherhood. His evidence is not without value as indicating the possible existence of a period of adolescent sterility among Fuegian girls.

In 1901, referring to the Basuto of South Africa Grützner (44) notes that although intercourse begins at puberty, it is very rare for a girl to become pregnant soon after (p. 114).

Since *effective* contraception is not practised among any primitive people of whom we have any knowledge (57), an observation such as Grützner's though of doubtful value is at the least worth recording.

Allen Webb (133), Professor of Descriptive and Surgical Anatomy in the Calcutta Medical College, published his observations in 1848 on menarche in Indian girls with the statement:

"I believe that even the fact of the existence of this function [*i.e.* menstruation] having been well established, is no proof of the girl being fit to become a mother, that is, to bear a living child. Almost the only instances I have known here, of instrumental labour in European-bred females, were from their having married too young" (p. 261).

TABLE 10

Gupta's observations on Hindu women of Calcutta, 1848

NUMBER OF CASES	AGE AT MENARCHE	AGE AT 1ST PREGNANCY	MENARCHE-PREGNANCY INTERVAL
2	11	11	— mos.?
1	11	14	3 yrs.
7	12	—	—
1	12	12	1 mos.?
1	12	13	1 yr.
6	12	14	2 yrs.
2	12	15	3 yrs.
5	13	—	—
1	13	13	— mos.?
7	13	14	1 yr.
2	13	15	2 yrs.
1	13	16	3 yrs.
1	13	18	5 yrs.
37	Average = 12.3 yrs.	Average = 14.1 yrs.	Average = 1 yr. 10 mo.

Through the agency of an Indian physician and scholar Babu Modusuden Gupta (45) Webb was able to obtain the ages of menarche in 37 Hindu women, 25 of whom had been pregnant and for whom the age at first pregnancy was available. Gupta's data is presented in Table 10.

Gupta's data for the 25 individuals who

had experienced pregnancy shows that 4 individuals, or 16 per cent, had conceived within the first year, 8 individuals, or 32 per cent, within the second year, 8 individuals, or 32 per cent, within the third year, 4 individuals, or 16 per cent, within the fourth year, and 1 individual, or 4 per cent, within the sixth year. First pregnancy did not occur until more than a year to three years after menarche in 80 per cent of the cases.

The first investigator to collect data systematically on the reproductive life of a non-European people appears to have been A.-T. Mondière, a physician with anthropological interests who, during the latter part of the last century spent some six years working among the inhabitants of Cochin-China. He reported his observations in 1880 (85), and later, in 1886 (86), reproduced them in summary form in an article. Hartman (52) quoted from this article in his 1931 communication to *Science* on the relative sterility of the adolescent organism, and in that communication the figures reproduced differ very slightly from those given by Mondière. Here Mondière's figures (Table 11) are reproduced from his monograph which gives the essential figures in somewhat more detail than in the article from which Hartman quoted.

It is possible that from the figures in Table 11 one year should be deducted from the ages at menarche and birth of first child to allow for the Chinese method of reckoning; this would, however, make no alteration in the duration of the sterility interval in the fifth column of figures. Mondière was much interested in the differences presented by the four groups in the duration of the menarche-parturition interval, and suggested that since the climatic conditions were identical for all these groups the difference in the intervals must be attributed to racial factors. He felt, however, that the rather considerable sterility interval in the Cambodian women was possibly in some way connected with the fact that among this people the husband, as a rule, was more than twenty years older than his wife. In each of the five groups the girl was generally married at the establishment of menarche.

TABLE 11

Mondière's observations on the women of Cochin-China, 1880

PEOPLE	NUMBER OF CASES	MEAN AGE AT MENARCHE		NUMBER WITH FIRST CHILD	AGE AT BIRTH OF 1ST CHILD		STERILITY INTERVAL*	
		years	*months*		*years*	*months*	*years*	*months*
Annamite	980	16	4	440	20	6	3	4
Chinese	106	16	6	15	18	10	1	6
Min-Huong	62	16	9	40	20	9	3	2
Cambodian	96	16	10	45	22	6	4	10

* The calculation of the sterility interval from menarche to conception (= −10 months from parturition) has been added by the present writer.

The results of this investigation led Mondière to the conclusion that the arrival of "nubility is more an affair of race than a matter of climate" (86, p. 824).

Among all these peoples contraceptive practises were entirely unknown and children greatly desired. Whatever Mondière's findings may actually mean, it is unnecessary to do more here than to suggest that they indicate the possible existence of a period of adolescent sterility

among the peoples of Cochin-China investigated by him.

In his articles "Nubilité" and "Puberté" in the *Dictionnaire des Sciences Anthropologiques* published between 1886-1894 Mondière clearly recognizes the difference between puberty and the period at which actual reproductive capacity appears. In the article on "Nubilité" he writes:

"Nubility is frequently confused with puberty, but it is a very different thing. With the establishment of nubility there follows not only the possibility, but the capacity for normal reproduction. Puberty manifests itself late or early, nubility exists only when the woman is without danger able to give birth to a new being. The sperm in the adolescent although secreted at the period of puberty does not perhaps possess the qualities necessary for producing a regular segmentation of the ovum; and in the young woman, if conception takes place, it is doubtful whether the foetus will be brought to term, and the pregnancy is excessively dangerous both for the mother and offspring. The age of nubility falls into the period of adolescence, that is to say from eleven to twelve years in the female until twenty or twenty-one years, and strictly speaking the term should be applied only to this period" (86, p. 823).

Similar views are expressed by Mondière in the article on "Puberté," (87, p. 941), in the same work.

More than thirty years ago Professor J. Preston Maxwell of Peiping Union Medical College carried out an investigation on 99 married women of Yung Chun in South Fukien, China, relating to menarche, marriage, first delivery, and footbinding. These data were never published by Professor Maxwell, and I am greatly indebted to him for his gift of them and his permission to use them in the present paper (Table 12).

The average age at menarche of these women was 16.13 years, with a range of 13 to 21 years. First effective intercourse took place at an average age of 17.38 years with a range of 13 to 23 years, and first childbirth at 20.02 years, with a range of 15 to 26 years. Table 12 represents the distribution in this group of women of the intervals between menarche and first childbirth irrespective of age; the figures

TABLE 12

Interval between menarche and first childbirth in 99 Chinese married women from South Fukien

INTERVAL.....	LESS THAN 1 YR.	1 YR.	2 YRS.	3 YRS.	4 YRS.	5 YRS.	6 YRS.	7 YRS.	8 YRS.	9 YRS.	NO. PREGNANCY
No. of cases.....	3	6	17	11	15	7	8	5	3	4	20
Per cent.....	3.0	6.0	17.0	11.0	15.0	7.0	8.0	5.0	3.0	4.0	20.0

TABLE 13

*Interval between menarche and first childbirth in 34 Chinese women married before the establishment of menarche**

Age at menarche.....	15–16	17–18	19–20
Number.....	14	13	7
Age at marriage.....	14–15	16	16
Age at first child.....	18–19	19–20	21–23
Number.....	11	13	6
Menarche-childbirth interval.....	3 yrs.	2 yrs.	2 yrs. 6 mos.

* All ages are according to Western reckoning.

make it clear that in only a very small percentage of cases is menarche followed by pregnancy within the first year. Of these women 34 had arrived at menarche from 1 to 5 years before marriage, as shown in Table 13.

The small number of cases available hardly renders Table 13 an impressive one, and since also Professor Maxwell's data were gathered in terms of years without record of months, this table is probably far from actually representing the facts; but such as it is, it does exhibit something

of a general trend, the younger 15–16 year age group apparently taking a longer time to overcome their initial infecundity, and being more often sterile (3 cases) than is the case in the older groups. This is again borne out by the figures for the whole group arranged by age at menarche, as is seen in Table 14.

This table gives a striking illustration of the gradual decrease in the sterility interval as the adolescent female arrives later at menarche. Similar findings have recently been obtained by Mills and Ogle (79) on data relating to white and negro mothers of illegitimate children. These investigators note that "The sterile lag period from menarche to first conception . . . exhibits a steady shortening as we go from earlier to later menarchial age" (p. 64). Such facts would suggest that the more mature the soma the shorter will be the sterility interval following menarche.

TABLE 14

Menarche-conception interval in 99 South Chinese married women

Number of cases	6	11	29	16	18	9	3	5	2
Age at menarche	13	14	15	16	17	18	19	20	21
Age at marriage	18	17	16	16	16	18	17	17	22
Age at 1st child	21	20	19	20	20	21	21	22	27
Number of conceptions	3	2	2	4	3	1	0	2	1
Per cent of conceptions	50.0	18.2	7.0	25.0	16.6	11.1	—	40.0	50.0
Menarche-conception interval	7	5	3	3	2	2	1	(1 1 yr.	5?)*

* The combination of the 20–21 year groups yields a more accurate figure of 1 year for the interval here.

Chau and Wright (19) in a report in 1925 of an investigation carried out on 2,291 South Chinese women living in sub-tropical Canton (N. Lat., 23° 7′ 10″) and surrounding districts, found the mean age at menarche to be 14.5 years; the mean age at marriage (683 cases) 17.6 years, and the mean age at birth (596 cases) of the first child 20.5 years. Only one girl became a mother at the age of 13 years; five at the age of 15, and twelve at the age of 16.

Clearly such figures are of very little worth for our purposes, although in a very general way they may be regarded as not without some suggestive value. Were we to take these data at their face value we should have to suppose an average sterility interval of some 6 years. One cannot be certain that such an average interval is at all unlikely. It may be recalled here that among the natives of Wogeo, in New Guinea Territory, menarche generally arrived at seventeen and despite frequent intercourse during the interim it was not usual for a girl to give birth to offspring until she was twenty-two; this yields a sterility interval of five years. However, until further investigations have been carried out in this and in other regions of the world it will not be possible to say with any degree of security whether such an *average* interval occurs in any human group.

Mills and Ogle (79) in a paper already referred to have presented the following data, collected from hospital records by Mills (Table 15).

From Table 15 it is to be noted that the fertility interval appears to be about three years longer in the married than in the unmarried except in the case of the Manila groups where the interval is practically the same for the married and the unmarried. The authors think the latter coincidence in age at first childbirth (6.33 years

after menarche) reflects "a real expression of physiologic sterility," since "sex relationships in Manila are perhaps as free from social or moral restraint as anywhere on earth" (79, p. 611). This may be so, but we are not told when effective intercourse begins in any of these groups, hence it does not seem to me that the figures in the last column can have any real significance for our purposes. This is, however, not the case when we examine the material for the interval between marriage and is followed by an average lag before the first conception (as determined by the deduction of 10 months from age at first delivery) of 2.00 years. It seems likely that the greater "fertility lag" in the married as compared with the unmarried is due to the fact that the married generally begin effective intercourse appreciably later than the unmarried. The figures for Manila relating to childbirth in the unmarried and the married may, as Mills and Ogle believe, reflect the actual

TABLE 15

*Menarche, marriage and first birth data**

CITY	SUBJECTS	DATE	NO.	MOTHERS AGE IN YEARS AT			LAG IN FERTILITY (MENARCHE TO FIRST CONCEPTION)
				Menarche	Marriage	1st delivery	
Cincinnati	Unmarried Negroes		33	13.44 ±0.13	.....	18.08 ±0.28	3.89
	White and colored, married	1924	131	13.68 ±0.08	19.09 ±0.17	20.48 ±0.19	6.05
Richmond, Va.	Unmarried Negroes		56	13.46 ±0.09	.....	18.21 ±0.19	4.00
	Married Negroes	1934	52	13.75 ±0.17	19.63 ±0.17	21.60 ±0.43	7.10
Panama	Unmarried Negroes		72	14.04 ±0.09	.....	19.26 ±0.20	4.47
	Married Negroes	1934	56	14.05 ±0.14	21.01 ±0.27	21.93 ±0.31	7.13
Manila	Unmarried Filipinos		22	14.73 ±0.16	.....	21.82 ±0.50	6.33
	Married Filipinos	1934	84	14.58 ±0.12	20.49 ±0.30	21.88 ±0.30	6.55
Hongkong	Married Chinese	1934	284	15.82 ±0.06	18.27 ±0.11	21.00 ±0.12	4.97

* After Mills and Ogle, Tab. I, (1936).

conception; for Cincinnati whites and Negroes the interval is 0.59 years; 0.37 years for Richmond married Negroes; immediate conception in Panama married Negroes; 0.59 years in married Filipinos at Manila, and 2.00 years in married Chinese at Hong-Kong. Hence, the only evidence of any significance yielded by this data is that although Chinese Hong-Kong married women arrive at menarche at an average age of 15.82 years and marry at an average age of 18.27 years, marriage existence of a physiologic sterility interval here of 6.33 years; we should, however, want to see much supporting evidence from Manila before we could accept such a figure as a fact. We have already seen that in two separate Chinese groups such a period of sterility has already been recorded by two independent investigators, but the same criticisms apply to their findings as to those of Mills and Ogle. Incidentally, it is desirable to point out here that Mills and Ogle's last column in

Table 15 is unjustifiably labelled "lag in fertility." This column obviously reflects nothing of the sort; what it gives is what is stated in the introduced parenthesis, namely, the interval between menarche and conception—a very different thing.

The 2.00 years interval following marriage (2.65 years after menarche) before the first conception among Hong-Kong Chinese may reflect the existence of a period of sterility; but what this may be due to is another matter. In spite of the statement of Mills and Ogle to the contrary I have been informed by Professor J. Preston Maxwell, Professor of Gynecology and Obstetrics at Peiping Union Medical College, that the desire for children is to-day by no means as great as it formerly was in such places as Hong-Kong, and that contraceptive practices are far from unknown among the native population. However, the low economic level of the Chinese here reported may be an additive factor in complicating the evidence. These objections, of course, apply to all the evidence which has thus far been cited. The evidence of Mills and Ogle, though clearly by no means conclusive, does at any rate, point in the direction of a probable adolescent sterility interval among the peoples cited.

A certain amount of material exists for Indian women which may be discussed here. In *Mother India*, published in 1927, Mrs. Katherine Mayo (75) drew attention to what she esteemed to be the fact that "The Indian girl, in common practice, looks for motherhood nine months after reaching puberty, or anywhere between the ages of fourteen and eight. The latter age is extreme, though in some sections not exceptional; the former is well above the average" (p. 22).

At the time of their publication these statements among others excited much indignation which found expression in the Indian press and elsewhere. But long before the advent of Mrs. Mayo's book the child-mothers of the East had become an established feature of orthodox Western tradition relating to the East. Child-mothers there are in India, but they are not usually to be found "between the ages of fourteen and eight." As long ago as 1848 Webb (133) had already shown that:

"It is not common for girls in India to begin to menstruate until after the 12th year. . . . Out of a list of 127 Hindoo females with which I have been favored, it began only in 6 girls under 12 years of age, and as many of them did not again menstruate until a year after this which they believed a *first appearance*, it is probable . . . that a ruptured hymen would account for that. Thus 81 out of 127 are stated to have been 12 years old or upwards.

"Out of eighty cases thus furnished who had probably been subjected to the influences of impregnation from the age of nine years, there were only 28 births under 14 years of age, but similar results would perhaps have followed in Europe. . . . Out of 127 cases reported to me of Bengalees, one birth is stated at 8, and one at 9" (p. 254).

According to more modern evidence, for example, the Indian Census Report for 1931 "the average age of females at marriage is 13.33 years and of males 17.98 years," the females seldom going to live with the husband until after puberty (in the Punjab, at least), (65). According to the Indian Census Report for 1921, the first child in the great majority of cases is born in the *third year* of effective marriage, i.e. dating from menarche (77). This puts the mean age of the mother at 16 years and some months. According to a statement, made in 1928 by Clark (21), of the figures from the Maternity

Hospital at Seva Sada in Amednagar in which Presidency early marriage is said to be more prevalent than in any other part of India, the average age of the mother at first delivery is 18.3 years. In 1927 Dr. M. I. Balfour (13) of Bombay, in an account of 6580 primiparous mothers from many parts of India, stated that none were under 13 years of age, 7 recorded as 13, and 35 as under 15. The average age of the mother at the birth of her first child was 18.7 years in Bombay, and 19.4 years in Madras. In both Bombay and Madras respectively 85.6 and 86.2 per cent of the mothers were more than 17 years of age. These figures show that less than 1 per cent of Hindu women were mothers before they were 15 years of age and none before the age of 13.

An analysis of Curjel's (25) report of 1920 on menstruation in 545 Calcutta women of various social classes yields a mean age of 14.21 years for age at menarche, a figure which would give an average adolescent sterility interval for the Indian woman of approximately 4 years. It may be noted here that in 1930 Pillay (98) stated in connection with Calcutta women that "An analysis of about 700 cases shows that the age of puberty is 13 or 14, and the age of the birth of the first child is 14 or 15."

These statements would, upon the face of them, seem to be extremely doubtful; at any rate, they are lacking in confirmation, and, unfortunately, Pillay does not present the detailed figures upon which they are based.

The imaginative order of Mrs. Mayo's statements is, I think, fairly clear; not that the evidence which has been cited in this connexion is altogether satisfactory; it is not, and we have yet far to go before accurate and reliable data will become available for conditions in India; but such as it is, this evidence does render Mrs. Mayo's statements extremely doubtful. The fact is that the youngest mother seen by Mrs. Mayo was, as she herself records, 12 years of age; and *she* was probably older! It is a fact, perhaps not too well known, that white observers almost invariably underestimate, by years the ages of native children, who, owing to undernourishment and a variety of other factors appear so much less developed than white children at similar ages. Reche (103) has suggested that this is in part due to the lateness with which the secondary sex characters appear in such children. It is of some interest to note that in the adults of such peoples the tendency is greatly to overestimate the age of individuals (1). Professor C. A. Mills informs me that during his widely extended investigations among native peoples in various parts of the world it was invariably his experience that when he was able to check his own estimate of the age of an adolescent or a child by some official birth record, he always found his own estimate to be too low. Actually it is extremely doubtful whether there exists any people among whom the mean age at menarche is less than 13 years.

Nicora (90) in a paper published in 1938 reports that out of 390 pregnant Italian girls ranging in age from 11 to 17 years only one girl became pregnant before the commencement of menstruation, while two others had only menstruated for 2 and 6 months respectively prior to conception; the remainder did not become pregnant until a more appreciable period of time had elapsed following menarche. It is not stated, however, when active intercourse commenced in each case.

Dr. Henry Greist who was superintendent of the Presbyterian Hospital at Point Barrow, Alaska, from 1910 to 1936, informs me that among the Eskimo of that vicinity although puberty and intercourse

commenced at a relatively early age (between 10 and 12 years?) pregnancy before fifteen years of age was extremely rare. Contraceptive practises were entirely unknown (42, 135).

It is, of course, perfectly well known that some girls in India, as elsewhere in the world, are capable of bearing children at a chronological age of less than 13 years, and that they may menstruate long before they have reached that age; in many cases the chronologic age at menarche may be unusually low (2, 26, 47, 59, 68, 90), but there can be little doubt that in normal cases the *physiologic* age, that is to say, the actual developmental status of such girls as measured against chronologic time, is commensurate with that of the chronologically older girls. Arbitrary chronologic standards of age, it must be clear, are only of secondary importance in the consideration of these matters. The well-authenticated cases of girls who, at 8 or 9 years of age, have borne children are relatively few, and though these cases are exceptional in terms of chronologic age for a normal population, there is more than a doubt that they are in any way exceptional in terms of physiologic age. At any rate, such cases being as rare as they are, do not have to be considered in discussing the normal conditions. A girl of less than 13 years of age may be as sexually mature as a woman of 25, and a woman of 25 may be as sexually immature as a normal girl of less than 13 years of age. Such cases are obviously abnormal, but the state of development in such cases does serve to explain why girls of the former class are able to conceive at so early a chronologic age.

DISCUSSION

The evidence cited in the foregoing pages quite clearly shows that the immature female who is less than 20 years of age conceives much less easily and much less frequently than the mature female up to 30 years of age; that a high percentage of these younger women are relatively sterile, and that prior to the age of 20 years the process of childbearing constitutes a hazard to the life of both mother and child which increases in proportion to the youthfulness of the mother and decreases to a minimum at maturity (30, 48, 67, 69, 87, 88, 90, 133). All the evidence has pointed strongly in the same direction, namely, to the conclusion that the immature female is biologically immature, developmentally unprepared, for the processes of reproduction; that when these processes are early initiated and exercised before maturity is reached the well-being of the mother and of the child is endangered. In young adolescent females there generally exists a pattern of conditions which in the largest number of cases tends to secure such females against undergoing an experience for which they are biologically not adequately prepared. This is putting the matter somewhat teleologically; it would, perhaps, be more correct to say that the adolescent organism being itself in process of development is not generally endowed with the capacity to perform the functions of reproduction until it has reached a certain stage of efficient differentiation. This latter stage depends upon the capacity, among other things, to produce mature ova; and this is a capacity which, as we have seen, there is good reason to believe is not attained in most mammals until some appreciable time after the appearance of the first oestrous or menarche.

The ontogenetic developmental history of all mammals consists in a process of differentiation in which organ-systems undergo a differential development, at rates and in regions which follow one

another in a definite serial pattern, at more or less definite moments of time as determined by the system in which the developmental process proceeds. The process begins with the fertilization of the ovum and terminates with the attainment of maturity. In the human female the evidence points to the age of 23 ± 2 years as the age of maturity. The optimal conditions for reproduction prevailing in the organism at that time, i.e. at the age of 23 ± 2 years, are maintained for about 5 years, at the end of which time the process of involution commences and at about 45 years expresses itself in the menopause, terminating finally with death. Puberty represents an early transition period in the total developmental process, during which maturation gradually takes place in certain parts of the reproductive system, and leads to the phase of development which we recognize as maturity, the period when the organism actually becomes capable of efficient reproduction. Puberty is the bridge which leads from childhood to maturity.

In what immediately follows we shall briefly discuss the developmental physiology of the primates with particular reference to the human species in so far as it relates to the functions of reproduction. We must determine to what extent, if any, the physiological evidence supports the idea of the existence of a period of adolescent sterility in the primates.

Development consists of growth, or increase in size, and differentiation, or increase in complexity. At fertilization the process of development is initiated in the ovum by the spermatozoon; there is immediate growth and gradual increase in complexity. Throughout the process of development growth seems to be one step ahead of differentiation. The spermatozoon contributes the determiners of sex in the form of a definite chromosomal structure which eventually leads to the development of one or another particular set of sex characters, according as the chromosomal structure is of the male or of the female pattern. The development of these characters in the mammals is presumably brought about by certain chemical agents which there is good reason to believe are already present at the so-called "sexually indifferent" stage of development of the organism: the stage during which the sex of the organism cannot ordinarily be determined save by reference to its chromosomal pattern. These chemical agents are probably related to or are identical with the *organizers* which have been postulated by Spemann as responsible for the early differentiation of tissues and the induction of organ formation; and it is not unlikely that these "organizers" are the primordial representatives of the growth and sex hormones of the older organism (134, 134a, 138). At any rate, it appears that from a very early stage in development the general somatic differentiation and sexual differentiation of the tissues of the organism proceed together, inseparably. All development, in short, is sexual development, the distinction between morphologic and sexual development being an arbitrary one. The process of development consists in the organization of tissues for the fulfillment of certain definite functions; structures have no other meaning than this, and apart from living the chief function of every organism is reproduction, and to this end all development would seem to proceed. Tissues and organs undergo development at rates and in regions which are related to one another in circumscribed serial patterns, so that one process or event cannot occur without exercising a definite influence upon others within the system; and the general pattern of development is such, throughout the animal kingdom, that the

functional qualities of a tissue or an organ are always preceded by growth and increase in complexity in such tissues and organs. The gradual development of the functions of the body system are dependent upon the rates of growth and differentiation of the tissues comprising it; and in the ontogenetic development of any animal a particular succession of changes must occur before any one of these functions can be established. So it is with the development of the structures and functions devoted to the reproductive system. These do not appear in the newborn infant in a state ready for the performance of the processes of reproduction, but a long period of years must elapse during which the necessary changes must occur which eventually render reproductive activities possible.

The great characteristic of development as a spatio-temporal phenomenon is its gradualness.

It is to-day a fairly well established fact that at birth the individual is in possession of most of the elements necessary for reproduction. Thus, ova are present in the ovaries, and the pituitary contains gonadotropic hormones (119, 139), these when injected into older animals are capable of inducing ovulation in the latter. Anterior pituitary hormones, as a rule, are incapable of producing ovulation in the newborn animal. As the animal grows, however, ovarian reactivity to the hormone becomes established, and as sexual maturity is approached the amount of hormone necessary to produce a given reaction progressively decreases. While the ovary is capable of reacting to gonadotropic hormones already present in the anterior lobe of the pituitary at a very short time after birth, yet under normal physiological conditions it does not do so until long afterwards. It has been suggested that this is due to the fact that though the pituitary contains gonadotropic hormones at this early stage, they are not poured into the blood before a definite stage of development has been reached (110).

Whether the increasing reactivity of the ovary is due to an increase in the effectiveness or quantity, with age, of the substances acting upon the ovary, or to an autochthonously developing sensitivity of the ovaries themselves, the available evidence renders it certain that the processes leading to the development of ovulation are of a very gradual nature (19, 24, 32, 33, 34, 52, 53, 110, 121, 150).

In order that a female animal may conceive and bring the process of pregnancy to a successful termination, it is necessary that her ovaries should be able to produce mature ova capable of being fertilized, then implanted in the uterus, and there acted upon in such a manner as to cause the fertilized ovum to undergo development up to the stage when the developed organism is ready for birth. All these processes require the presence in the maternal organism of a number of conditions. Without the presence of any one of these conditions reproduction cannot occur. These conditions come into existence in a definite order in physiologic and chronologic time, before the establishment of which as a functional complex the female cannot reproduce. If she is not yet able to ovulate she obviously cannot be impregnated, and if she is able to ovulate the absence of a luteinizing hormone may make it impossible for the fertilized ovum to become attached to the uterine wall. Now, it is just these two conditions, ovulation and formation of the corpus luteum, which do not normally become functionally established until some time after puberty, if in the conventional sense we here take puberty to mean the

period of the first oestrous or menstruation.

Van Herwerden (129), Allen (3), Hartman (51), Corner (23), and others, have shown that the early menstruations of the female rhesus monkey are normally unaccompanied by ovulation. It is thus impossible for the early menstrual rhesus female to conceive. There is good reason to believe that the same holds true for the human female (52). What happens at puberty is this: As the general process of growth, over which the growth hormone of the anterior pituitary has presided, slows up, this gland pours into the blood stream a hormone, the follicle-stimulating hormone, which has the effect, *ceteris paribus*, of activating the ovary to elaborate a hormone, oestrin, which is not only responsible for the gradual appearance of the secondary sex characters, but also for the induction of all those changes in the reproductive tract which result in menstruation. Ovulation, however, does not and cannot occur as the result of the action or in the presence of, oestrin alone; at puberty oestrin is alone present in appreciable amount. For ovulation to take place another fraction, or hormone, of the anterior pituitary must come into play, and this is the luteinizing hormone. Unfortunately, it is not known at what age an amount of luteinizing hormone sufficient to produce ovulation makes its appearance in the blood. Actually it is not altogether certain whether the follicle stimulating and luteinizing hormones exist as separable fractions or merely represent different states of a single gonadotropic hormone (111), or whether the ovary itself undergoes a series of differential changes for quite other reasons which eventually enable the gonadotropic hormone to call forth the proper response. But whatever the facts may be it is known that oestrin, which is alone sufficient to produce those overt phenomena which we collectively term puberty, briefly, the appearing secondary sexual characters and early menstruation, is not sufficient to produce ovulation. Hence, it is clear that the first or early menstruations must be unassociated with ovulation; and, therefore, it is impossible for a female, under normal conditions, assuming the non-ovulatory character of the early menstruations to be the normal condition, to conceive in the early phase of puberty.

How long this early or primary phase of puberty lasts in the human female it is at present impossible to say. The period is, no doubt, a very variable one, and is probably linked with genetic factors the expression of which is doubtless subject to modification by environmental factors.

It is only when the second hormone of the pituitary, the luteinizing hormone, is poured into the blood stream in sufficient quantity, or the ovary reaches the proper stage of differentiation or sensitivity, following the establishment of menarche, that ovulation and impregnation become possible. This is the period of *nubility*, and as more than one earlier author has pointed out, is not to be confused with the earlier period of puberty. We have already seen that in the lower mammals and in the subhuman primates, nubility generally follows puberty only after a fairly appreciable amount of time has elapsed. Such evidence as we have for man indicates in no uncertain manner, that a similar appreciable interval of time must separate the two events or periods in the human species.

Gynecologists such as Waddy, Joulin, and Matthews Duncan, had already clearly recognized this fact three-quarters of a century ago, but the scientific world allowed their suggestive evidence to pass unnoticed, and it has remained for modern experimental research in the physiology

of sexual development and reproduction of the lower mammals to rediscover and to provide the scientific demonstration of the truths of these early investigators. Something of the nature of this demonstration it has been attempted to give in the above passages. We may now, however, examine, and perhaps anticipate some of the possible objections to the interpretation of the meaning of adolescent sterility here given.

It is a well known fact that many apparently healthy girls have given birth to children at such early ages as 8 and 9 years, and that many such girls exhibit the characters of mature women, (2, 39, 47, 48, 66, 68, 84, 90, 104). In individuals of the latter variety some disorder of the ovaries or adrenals is usually, though not always, demonstrably responsible. In many cases where no pathologic process can be demonstrated it is nonetheless possible that such a process is at work, but in so many others it seems quite unnecessary to look for a pathologic factor, for what has impressed students of many of these cases of early motherhood and precocious sexual development, has been the fact that, as Harris (48) put it in 1873, in these girls their "physical development [is] in correspondence with their sexual" development, "and the whole system is in correspondence with it, so that the function [i.e. menstruation] does not, in its performance, interfere with the growth or health of the subject," (47).

In such cases of premature sexual development we are dealing with a general speeding-up of the normal processes of development, so that a girl of a chronologic age of 10 years may actually be of a physiologic or developmental age in all or most of her characters characteristic of a woman of 25 years or more. Such cases are merely a further illustration of the fact that reproductive capacity is dependent upon physiologic development. Chronologic age is altogether unimportant here; physiologic age is the important thing. Early chronologic reproductive capacity is a striking thing only because it happens to present a deviation from the modal chronologic age at which women usually become capable of bearing children. Such deviant individuals are deviant only because of the rate at which they have developed, but in all other respects they are physiologically normal.

With respect to those cases in which the sexual precocity is traceable to some abnormal initiation of endocrine activity, which like magic ceases upon the removal of the exciting agent, usually a tumour (18, 39, 66, 68, 104, 144), such cases, when they occur in pre-pubertal or adolescent individuals, merely constitute a further illustration of the fact that development towards maturity is dependent upon the functioning of certain organs, and that in the normal individual the functions of these organs are only gradually established, but that in such individuals these functions may come into action prematurely as a result of the abnormal excitation of the organs regulating them.

Such cases do not, of course, present anything irreconcilable with the evidence for the existence of an adolescent sterility interval in man, or in any other animal species. Finally, it may be added, that while we nearly always hear of the child who has given birth to an infant, we very rarely hear of the numerous children who at one time or another have been exposed to sexual attentions from men, without ever conceiving. Yet there can be no question that such cases occur in our own and in other societies.

An important fact which was first brought out in 1931 by Hartman (52) in connexion with his studies on macaques, was that maturity, or the period at which

his animals were first able to conceive, was correlated with their general body growth with particular reference to weight. In his animals menarche occurred at an average body weight of 3000 grams, but ovulation and fecundity were not attained until the average weight of 5000 grams was reached, thus representing a sterility interval of about one year. That maturity in the present particular sense as well as in the more general sense in which the term is used is a function of growth is obvious. In the recent study by Schultz and Snyder (114) on the reproduction of the chimpanzee it has been suggested that the sterility interval is related to the entire growth period in an inverse manner, according to the formula: the shorter the growth period the longer the sterility interval. Thus, these authors wrote in 1935:

> . . . "observations available so far, seem to indicate that the period of so-called adolescent sterility is longest in the most primitive form, the macaque, appreciably shorter in the higher primate, the chimpanzee, and shortest, if indeed existing at all, in man. These differences are all the more significant in view of the fact that the entire growth period is shortest in the macaque (about 7 years), much longer in the chimpanzee (11 years) and longest in man (20 years)" (p. 198).

But does it not appear more likely that if the entire growth period is longest in the higher primates that the periods of infancy, childhood, adolescence, and maturity would be somewhat more extended in duration in them as compared with the lower primates in which the growth period is somewhat shorter? Indeed, this has long been known to be the case, and has recently been abundantly demonstrated by Spence and Yerkes (123) for the chimpanzee as compared with man. It might be further argued that if the adolescent period is of greater duration in the higher primates, that is to say, the period elapsing from menarche to primary fecundity or nubility, then *ipso facto* the sterility interval should be longer in the higher primates than in the lower primates. Certainly the interval appears to be considerably greater in man (3 years?) as compared with macaque (1 year?). As for the chimpanzee only 4 reliable records are at present available and these give sterility intervals of respectively 4, 10, 12, and 13 months. What the actual degree of variability and the mean duration of this period is in the chimpanzee it is at present hardly possible to say, but until further reliable evidence becomes available it seems reasonable to assume that in these respects the chimpanzee resembles man more closely than it does the macaque—in the present indicated sense, and not in that suggested by Schultz and Snyder. Where the latter appear to have erred is in their original uncritical acceptance of Hartman's (54) statement that "no adolescent female has conceived during the first two years after puberty" (p. 23). We have already seen that the correct figure is actually about 1 year, as originally given by Hartman (52) in his 1931 communication.

Furthermore, the fact that many apparently normally developed girls are capable of conceiving immediately after the appearance of menarche does not constitute a disproof of the fact that a still larger number of girls are incapable of conceiving at this time; and *that* is the important point. If the overt evidence did not indicate as much, our knowledge of the physiology of sexual development in the human female would demand it.

CONCLUSIONS

The evidence presented in this paper strongly supports the view that in the females of the mammals thus far investigated, namely, mouse, rat, macaque,

chimpanzee, and man, the ability to reproduce is not, in the large majority of cases, synchronous with the appearance of the first oestrous, or the first overt expression of puberty, the menarche. The physiological prerequisite of reproduction is ovulation and its associated processes; since these do not normally develop until some time after the advent of puberty, conception and reproduction are therefore impossible at the inception of puberty. Before ovulation can take place the endocrine system and the soma must reach a certain level of development; when this level of development is attained ovulation then takes place, and the organism is then said to be ***nubile***, the state of development at which it becomes capable of conceiving and reproducing. Nubility and puberty are stages of development which are often confused with one another, but in reality they represent two very different developmental stages. The interval from the inception of puberty to nubility is termed the ***adolescent sterility interval***, the period of adolescence during which the animal continues to be functionally reproductively sterile. Obviously, this interval is not, because of its sterile character, distinguishable from any of the preceding periods of development; it is here merely termed the adolescent sterility interval in view of the necessity of emphasizing what appears to be the fact that puberty and the power to procreate are not synchronous events, but that the arrival of the one is separated from the development of the other by an appreciable interval of time, and that this interval represents a period of time during which the organism continues to be sterile. This is not generally recognized to be the case. Puberty is most commonly believed to be the sign of the development of the capacity to reproduce, and the only interval at all recognized is that between puberty and maturity, the period of adolescence. Maturity is generally taken to be the period which commences at the time when the growth of the organism comes to an end, in man at about 23 ± 2 years. This view, the evidence indicates, does not appear to be sound. The period of adolescence does begin at puberty, but the power to procreate follows only at some time after this developmental stage has been attained,—at the period of ovarian maturation when ovulation becomes possible, and when conception may follow, the period of nubility. This period, that is nubility, is not coincident with maturity but represents the bridge, as it were, between puberty and maturity; maturity being attained only at an appreciable time after the development of nubility. The period of nubility is not by any means the best time for procreation; it is, on the other hand, the worst, being characterized by high maternal and infant mortality (67, 69). The best time for reproduction is unquestionably at the age of early maturity, when the female organism is fully prepared to undertake and carry through the processes of reproduction satisfactorily.

The physiological basis for the period of adolescent sterility is clear: it is simply that the endocrine glands which must pour their hormones into the blood stream before ovulation and reproduction can take place, do not normally do so during the menarchial or immediately postmenarchial period, but only at a later stage of development, which we then term the period of nubility.

The period of nubility is, among other things, only the mark of a step in the maturation of the sexual equipment for the process of reproductive functioning; it does not by a long way represent the completion of that maturation, but only the beginning. Hence, we would define

puberty as the period of the inception of those changes in the reproductive system which are exhibited in the appearance of the first oestrous or menarche, and in the gradual development of the secondary sexual characters.

Physiologically this means that the pituitary now elaborates the follicle-stimulating hormone which acts upon the ovary in such a manner as to cause the latter to produce its own hormone, oestrin, which in turn acts upon the genital tract in a specific manner and results in the appearance of the first oestrous or menarche, and the development of the secondary sexual characters. At this stage of pubertal development the organism is normally sterile.

The changes in this way initiated at puberty are followed, after the lapse of some time, by a unique development, namely, ovulation; this marks the period of nubility, which may be defined as that period of development in which the function of ovulation is established in the growing organism.

Physiologically this period is characterized by the secretion of a second hormone of the pituitary, the luteinizing hormone, which acts upon the ovaries in such a way as to cause an ovum in one of them to burst through the ovary and to pass into the uterine tube, leaving behind its follicular investment, which in the wall of the ovary undergoes reorganization into a luteal body the secretion of which, progesterone, prepares the uterus for pregnancy.

The actual duration of the sterility interval in mouse, monkey, chimpanzee, and man, would appear to be respectively, one month, twelve months, four to thirteen months, and three years. Variability in respect of the duration of this period is, of course, the rule, but the precise limits of this variability in any of these groups remains to be determined; nonetheless, it is clear that in the chimpanzee and in man this variability is quite appreciable. In about 25 per cent of mice conception is possible at first oestrous, but conception at first oestrous in the macaque has so far been unrecorded; it is, however, not altogether unlikely that in some macaques conception is possible at first oestrous, although one year seems to be the normal interval between first oestrous and first conception. In man the observations of anthropologists and gynecologists would indicate that the interval between puberty and nubility is, on the whole, of about three years duration; but the variability in the human species in this, as in other respects, is apparently very considerable, and it is probable that genetic differences, expressed in differences in the duration of the interval, exist between different local groups of mankind.

That a period of adolescent sterility normally exists in most human females is a fact substantiated as much by the observed phenomenon, as by the nature of the physiological processes involved in the maturation of the reproductive system; this evidence alone strongly suggests that during early adolescence the organism must, in most cases, necessarily be sterile.

The fact that the existence of such a period of infertility in the post-pubertal adolescent girl has escaped the attention of most human beings is not as difficult of comprehension as may at first appear. How the belief that the first menstruation represents a token of the girl's arrival at the procreative stage of development came into being it is impossible to tell. It may be that it had been independently noted in various human groups that women remained sterile as long as they had not reached puberty (the first menstruation), that after puberty women

menstruated periodically, and that during their menstrual life alone were they capable of bearing children; for after the final cessation of these periods (menopause) they were again sterile. Women capable of menstruation were therefore considered to be capable of child-bearing. Hence the appearance of menstruation was taken to be the sign of the ability to procreate. The inference is certainly a logical one, but it is not wholly true, and unless the conditions are such as to make the observation a simple matter there is no possible way in which the falsifying factors in this inference would become apparent to sense. Since these conditions do not, in most human societies, exist, it is practically universally believed that the first menstruation is a sign of the ability to procreate. We have shown that there is good reason to believe that this is not the case.

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THE PROCESSES OF EVOLUTION

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UNTIL the appearance of Darwin's *Origin of Species* in 1859, the idea of organic evolution was by no means an established factor in biological thought. The instability of species had been suggested more than once and definite systems of evolution had been formulated by some writers, but it remained for the tremendous weight of evidence presented by Darwin to make a permanent impression on the scientific world.

There is a valuable lesson in this fact. In the modern scientific world we are prone to be impressed by bulk, especially when it is the bulk of extensive experimental evidence. Just as definitely are we prone to discount a purely logical analysis of any topic. The weakness of the position should be evident, but unfortunately it seems often not to be, for masterly summaries of experimental data continue to arouse admiration and we continue to follow the trails that they blaze even when logical analysis points elsewhere. Darwin's own contribution and the corollaries added by Weismann and others have themselves demonstrated this weakness, for through able support Darwin gained for the partly fallacious theory of natural selection a degree of acceptance that has since proved wholly unjustified, and any corollary that could be seized upon for the support of this position has been used, whether logical or illogical, established by experiment or wholly without such evidence. Our reasoning in evolution has very definitely shown the frailties of human prejudice, as well as the beauty of precise scientific thought.

It seems wholly beyond question that the attention of biologists to evolution should now be concentrated on the cold logic of the problems involved, in the expectation that the remaining gaps in our evidence might thus be made clear and subjected to sound experimental investigation. Instead the principal trend seems to be a rhetorical denial of the views that have been either neglected or difficult to investigate, and a positive argument for the views that have found favor, even to the extent of maintaining that the vital gaps in the supporting evidence are not insurmountable, since there is still possibility of their being filled! To argue that possibilities on one side of a question are not to be considered because experimental proof is lacking, and that possibilities on the other side are to be accepted in spite of lack of evidence because they are logical possibilities involves a naïveté that one would scarcely expect in scientific writing.

The writer's attention has been drawn again to this question primarily by Dobzhansky's *Genetics and the Origin of Species*, a magnificent contribution to the literature of evolution, even though, unfortunately, it is guilty of the faults just mentioned. As a discussion of the subject indicated in the title, it is certainly the finest yet produced, but its very fineness endangers the general consideration of evolutionary processes by minimizing all factors that cannot be encompassed by such a title.

When, in addition, the reader encounters such statements as this:

> "As to the direct adaptation, experimental data give no support for believing that such a thing exists. This question has been discussed almost *ad naustam* in the old biological literature, . . . we may refrain from the discussion of it altogether." (P. 31.)

he will certainly not be influenced toward a broadly unbiased view. Another statement made previously on the same page is as follows:

> ". . . the nature of the mutational changes in the genes remains unknown. This is, of course, neither surprising nor discouraging, for an understanding of the nature of mutations presupposes a knowledge of the nature of the genes as such, which remains as yet one of the distant goals of genetics."

Such an attitude arouses grave suspicion that still another statement (p. 186) may come home to roost, viz., that ". . . the 'theories of evolution' arrived at by different investigators seem to depend upon the personal predilections of the theorist."

Within the scope of such a brief paper as this it is obviously impossible to comment point by point upon the materials of an entire volume. Indeed, no need for such comment exists in the writer's mind for he accepts the work in general as has been stated above. As for his own detailed attitude, it was expressed in *The Problems of Evolution* (1931) in sufficiently general terms to permit brevity and inclusiveness, and nothing published in the interim has shaken the analysis then expressed. However, three years of work in the study of an insect species which were wasted so far as its relation to the process of evolution is concerned, have developed a very vivid appreciation of the difficulties that will beset the biologist who wishes to undertake the program of investigation recommended in this book. In the course of their long evolution, existing species have gained a remarkable degree of autonomy. It will evidently not be a simple matter to find a form that is favorable for the experimental study of the neglected phases of evolutionary change.

For brief comment, the evolutionary *impasse* may be concisely expressed as the old controversial matter of hereditary variations versus acquired characters. The terms are not well taken, but they persist from the older literature and serve as convenient labels. In the strict sense, the acquired characters of evolution may be defined as the expression of hereditary potentialities in the individual according to specific conditions of its environment. It has been abundantly demonstrated that no evidence of such individual reaction is to be found in the next generation save when it appears again in association with the same environmental conditions. As to hereditary variations, the acceptance of a hereditary genetic complex leaves us with no explanation of the very foundation of evolution, viz., the origin of differences. Darwin and his followers erred in this detail, Lotsy erred here also in his work on hybridization, and modern geneticists have either fallen short of an explanation of evolution or have committed themselves to the extremely narrow concept of origin through the influence of radiation.

Assuming the correctness of the basic concept of modern biology that living substance was originally a homogeneous mass, the acquisition of diversity permits no assumption of previous diversity. It is possible and logical to argue, as the writer has done (*op. cit.*, pp. 178–179) that in the existence of such a primordium the only variable factor is the environment, and that the impact of environmental fluctuations on the living substance must have been the initial source of change through the resulting varied reactions of

this substance. The opinion seems so clear that it should clarify our approach to the whole subject, but unfortunately the modern world fails to provide us with primordial living matter for experiment.

Certainly the development of any living substance through the ages, however simple or complex it may have been in the beginning, could have taken place only if it possessed or acquired the power to exist in harmony with a fluctuating environment, so that today we are faced with an extremely variable living world in addition to the variable environment as the field in which we must work.

In this field we witness hereditary changes in the organism and label them mutations without knowing just how they arise. We also witness the remarkable plasticity of living things in meeting the fluctuations normal to their environments, and in some cases we see in them visible results of their reaction to environmental stimuli. These results are an expression of hereditary potentialities. They do not persist in the heritage. The effect of such responses upon the hereditary potentiality has not yet been satisfactorily investigated, but it appears to be the only significant point of attack on this problem. We know that a functional capacity increases in the individual as it responds to persistent and increasing stimulus, but whether the offspring of individuals that have undergone such development have any greater capacity for such a response than the original heritage would have provided, we do not know. We know also that the response of individuals may bring about results that resemble mutant characters, and that the two do not behave the same, hence the modern geneticist must dispose of these spurious imitations as phenocopies, lest they steal some of the glory of true mutations. Here again is a confusing situation.

The chief obstacle in these discussions seems to be the persistence of emphasis on individual responses or acquired characters that adjust the organism to the inciting environmental condition. The controversial pitting of this point of view against the adaptive adjustment of species through selective processes has been all too easy to maintain through the many years of argument over the nature of evolution. This antagonism is difficult to support when we admit the all-important principle that everything in the organism, great or small, adaptive or non-adaptive, structural or functional, results from the reaction of its heritage to its environment. If the body encounters a new condition, it responds within the capacity of the heritage and if it is incapable of responding to a significant environmental change, it perishes. In addition to directly adaptive responses like the tanning of the human skin, however, these reactions include many of a purely incidental nature, such as the varied colors and patterns of insects that occur in seasonal forms in response to varying light and humidity. All of these characters are evidence of the organism's capacity for change from its primary state, hence the evaluation of their evolutionary significance demands much broader concepts than the purely adaptive response of individuals to conditions of importance in their own vital reactions.

For many years it was a preferred attack among Neo-darwinian evolutionists to demand that their adversaries show how the reactions of the individual could possibly have any influence on the chromosomes or on the germ cells. It is quite evident that they are as much an expression of something already present in the hereditary complex as are any other characters of the individual. The real problem is to show whether or not the capacity of any gene for expression in the

developed characters of the body can be modified beyond its original limits through the exercise of that capacity in an unusual way or for an unusual period. Logically such a change is entirely in harmony with the expression of all vital functions, but it remains unproved.

Reference to the literature of modern genetics provides us with recent and significant statements of opinion on the variability of gene action. According to the prevailing concept of environmental response, anything external to the living unit under consideration is a part of its environment, and in the information now available on position effects such a relation is apparent. On this point Dobzhansky writes (p. 115):

> "A rapidly growing amount of evidence indicates, however, that the genes are not quite so impregnable and impervious to the influence of their neighbors as has been thought. . . . A change of the linear order of the genes in a chromosome may then leave the quantity of the gene unaffected, and yet the functioning of the genes may be changed."

This interpretation is not extended beyond relation of the gene to its neighbors, but even in this degree it is an indication that the expression of the gene is conditioned by surrounding factors. Something outside of itself determines in part the action of the gene.

The further assumption that conditions in the cell beyond the confines of the nucleus may also play a part in the expression of the gene is so perfectly admissible on the basis of our modern knowledge as to follow without detailed discussion. There is nothing extraordinary about any of these points. Rather, they are harmonious details of the process of interaction with environment that is fundamental in all life. The only point that remains uncertain is their effect on the functional capacity of the gene as a hereditary unit, and it is to an appreciation of the importance of this problem that this discussion is directed, not to the establishment of the personal predilections of the writer!

The poverty of experimental evidence bearing on this problem should be a warning in itself. Most investigations of individual reaction to environmental conditions have been limited to a few generations and none known to the writer has provided gradually increasing stimuli over a reasonably long series. The possibility of individual reaction to varied environmental conditions depends upon hereditary capacity for some latitude of response. If response out of the usual range can be demonstrated in one generation, there is no reason to suppose that the capacity for the usual response has been impaired. Quite the contrary, if capacity for an unusual response persists through generations of normal reaction, it is a definite proof that some latitude of hereditary processes will persist even though all possible degrees of expression are not realized.

Significant experimentation demands several conditions. First, an organism must be available that responds to some controllable and variable environmental factor with a visible bodily development. Second, the lethal degree of this variable factor must be ascertained, if it is of sufficient importance to the organism to have such an effect. For conclusive experiments this condition appears to be essential. Third, the environmental factor should be varied progressively little by little to determine how greatly tolerance can be increased in individual life. Fourth, a similar modification through a long series of generations should demonstrate whether or not the effects of individual response are cumulative through a hereditary series. In the case of non-adaptive

characters, the lethal point as an absolute test of the reactive capacity of the heritage is, of course, lacking, and the degree of response itself is the only measurable result of the changed environment.

As far as the writer knows, Woltereck's experiments with daphnids, Agar's with *Simocephalus*, and Sumner's with mice are the most noteworthy experiments of this type. Although they lack some of the factors outlined and offer rather meager evidence, they gave results strongly suggestive of the transmission of some modification of hereditary capacity.

The possibility also exists that response to a specific environmental variation of small degree may not be a visible change in the organism, but that repeated impact of this condition may ultimately bring about a change. A further possibility exists of an immediate reaction in the soma or in the cytoplasm, and of an ultimate change in the genes as an adjustment to their changed surroundings. It is entirely probable that any such change would be non-adaptive—a purely incidental result of moderate chemical change in the living substance. As such it would apparently be hailed as another mutation, and the march of modern genetics would continue uninterrupted if the environmental factor persisted or the gene were actually changed.

In view of such possibilities no analysis of evolutionary processes can be complete and final until it disposes of the several questions raised. When we can bring experimental evidence to bear on the following points we shall be nearer to another step in evolutionary theory than we have been since the rise of modern genetics in the first decade of the century. We must know whether the response of the individual heritage is capable of influencing the capacity of the hereditary substance for like response. We must know whether continued response through a series of generations is capable of influencing hereditary capacities so that they may ultimately be independent of the original causative environmental stimulus. Finally we must know whether the changes resulting from response to environmental conditions may gain significance in the life of the organism in relation to other factors in its environment, as was proposed by Cuénot in his theory of preadaptation.

From the point of view of the geneticist it is highly important to know also whether the gene mutations and other types of chromosomal change may become significant to the species as it maintains itself in nature or under an approximation of a natural environment. The *possibility* alone is of no more real value in the materials of evolution than the *possibility* of purely Lamarckian results.

It is unfortunate that biologists find it so difficult to leave behind them the prejudices of an earlier day in this field of thought. We are in grave danger of evading important lines of investigation because of the fear of being Lamarckian, and in equally grave danger of being drawn by the truly magnificent accomplishments of genetics into a false assumption of the adequacy of this science in the explanation of evolution. Surely it is time for us to be scientific here as in other matters, to classify both our facts and our hypotheses according to their merits with full recognition of the limitations and the promise of each, and to work efficiently toward the establishment or disproof of the uncertain points.

There can be no reasonable doubt that gene mutations, polyploidy, translocation, and all of the other corollaries of modern genetics have a place in evolutionary change. These factors, together

with selective and isolating processes in the environment, may well be of great importance in the evolution of the complex populations of the present. We cannot explain evolution as a basic process, however, without accounting for the origin of diversity in an originally homogeneous primordium, and when that is done, diverse hereditary mechanisms themselves should prove to be resultants, not causes, of evolution. Whether the demonstration of this relationship can ever be satisfactorily accomplished with the complex mechanism as an inevitable part of the experimental material, remains to be proved.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *1901 East Madison Street, Baltimore, Maryland, U. S. A.*

BRIEF NOTICES

EVOLUTION

THE ENVIRONMENT AND HISTORY OF THE TOROWEAP AND KAIBAB FORMATIONS OF NORTHERN ARIZONA AND SOUTHERN UTAH. *Carnegie Institution of Washington Publication No. 492.*

By Edwin D. McKee. Carnegie Institution of Washington, D. C. $3.00 (paper); $4.00 (cloth). 10 x 6¾; viii + 268 + 48 plates; 1938.

This somewhat technical treatise covers the Permian deposits of the Colorado valley in Arizona and Utah. Formerly the Kaibab formation was called the Aubrey, but that latter name is now construed to include the Toroweap as well, and the name Kaibab has come into use to designate the Aubrey in its original restricted sense. Below the Toroweap lies the Coconino, a carboniferous deposit. Above the Kaibab lies the Triassic. Thus the Kaibab and the Toroweap together include all the Permian rocks of this region. The Permian rocks are of course unconformable with those above and below them. Also the Kaibab and the Toroweap are themselves separated by unconformity—but this unconformity is of a different type.

All the invertebrate phyla are represented among the fossils of these rocks, but only the brachiopods have been singled out for separate treatment. Of these, twenty-eight species are described, of which eight are new. Usually, in publications of this sort, only the new species are described, the old ones being merely mentioned by name, but since the established species are the important ones in synchronization of strata, their descriptions are much the more helpful. The plan of describing all species as the author has done is much more acceptable, and it is only to be regretted that the entire animal kingdom has not been covered systematically.

The photographic plates are excellent, and the index and bibliography quite exhaustive.

PATTERNS OF SURVIVAL. *An Anatomy of Life.*

By John H. Bradley. The Macmillan Company, New York. $2.25. 8⅜ x 5½; 223; 1938.

"If there is any meaning for mice or men in the restless drive of life, a billion years of living should contain it. To search those years for that meaning will be the object of this book." So writes Bradley (p. 5), remarking further (in something like an aside) that "part of the business of being human is to costume somber facts in pleasing fancies" (p. 21). Bradley has succeeded marvelously in his secondary purpose; the "facts" might not be recognized by their own fathers. As one of Bradley's fellow paleontologists

wrote recently in a review of his book, "his ideas are sure shots at the mark, and beyond." Indeed, they go beyond the beyond. Bradley retells the story of evolution, stressing theory to the almost complete exclusion of evidence, and reducing the speculative efforts of the leading evolutionists to picturesque if not astounding epigrams. Originally some of the chapters were published as magazine articles. In that form they would appear as they should—as metaphorical entertainment. Unfortunately, the meaning of life is not disclosed. As Bradley says, at the tip of his tale, "It is not for the historian of life to say. Self-directed evolution, so far as he knows, is an adventure without precedent in a billion years."

STUDIES ON CENOZOIC VERTEBRATES OF WESTERN NORTH AMERICA. *Contributions to Palaeontology, Carnegie Institution of Washington Publication No. 487.*

By Robert W. Wilson, John R. Schultz, Hildegarde Howard, Edwin H. Colbert, J. D. Laudermilk, and P. A. Munz. Carnegie Institution of Washington, D. C. $4.00 (paper); $4.50 (cloth). 10 x 6¾; 281 + 48 plates; 1938.

The following papers are herein presented: (1) New middle Pliocene rodent and lagomorph faunas from Oregon and California (19 pp., 3 plates), by Robert W. Wilson; (2) Pliocene rodents of Western North America (52 pp., 2 figs.), by Robert W. Wilson; (3) A late Cenozoic vertebrate fauna from the Coso Mountains, Inyo County, California (34 pp., 8 pls., 3 figs.), by John R. Schultz; (4) A late Quarternary mammal fauna from the tar seeps of McKittrick, California (104 pp., 17 pls.), by John R. Schultz; (5) The Rancho La Brea caracara: a new species (23 pp., 3 pls., 1 ch.), by Hildegarde Howard; (6) Pliocene peccaries from the Pacific Coast region of North America (28 pp., 6 pls., 4 figs.), by Edwin H. Colbert; and (7) Plants in the dung of *Nothrotherium* from rampart and Muav caves, Arizona (10 pp., 11 pls., 1 fig.), by J. D. Laudermilk and P. A. Munz. These studies, with their careful workmanship, excellent illustrations and literature lists form a valuable addition to palaeontological literature of Western North America.

DIE PHYLOGENIE DER WIRBELTIERE AUF PALÄONTOLOGISCHER GRUNDLAGE.

By Oskar Kuhn. Gustav Fischer, Jena. RM. 4.50. 9½ x 6½; viii + 94; 1938 (paper).

This is a brief but complete summary of paleontological data concerning the phyllogenetic histories of the vertebrates. As is the usual procedure with works on this subject, the author begins his story with the Agnatha and ends it with the primates. The author does not herein subscribe to any theory of descent, but merely attempts to present—by sorting out the more important findings of the tremendous volume of literature, especially that of the last decade—a factual picture of the origin and development of the vertebrates.

Seventy-seven excellent illustrations are included in the 92 pages of text. There is an index of subjects.

MIOCENE AND PLIOCENE FLORAS OF WESTERN NORTH AMERICA. *Contributions to Palaeontology, Carnegie Institution of Washington Publication No. 476.*

By Ralph W. Chaney, Maxim K. Elias, Erling Dorf, Daniel I. Axelrod, and Carlton Condit. Carnegie Institution of Washington, D. C. $3.00 (paper); $4.00 (cloth). 10 x 6¾; 272 + 27 plates; 1938.

The following papers, which will be of much interest to palaeobotanists, are included in this volume: Late Tertiary floras from the high plains, Ralph W. Chaney and Maxim K. Elias, with a chapter on the Lower Pliocene vertebrate fossils from the Ogallala Formation (Lavern Zone) of Beaver County, Oklahoma, by Curtis J. Hesse (pp. 72, 7 plates, 11 text figures); A Late Tertiary flora from southwestern Idaho, Erling Dorf (pp. 51, 3 plates, 2 text figures); A Pliocene flora from the Mount Eden beds, southern California, Daniel I. Axelrod (pp. 58, 6 plates, 1 text figure); The Deschutes flora

of eastern Oregon, Ralph W. Chaney (pp. 31, 7 plates); The San Pablo flora of west central California, Carlton Condit (pp. 51, 7 plates, 1 text figure).

DIE ENTSTEHUNG DES LEBENS *durch Stetige Schöpfung.*

By Ignaz Lichtig. N. V. Noord-Hollandsche Uitgevers Mij., Amsterdam. (Obtainable in America from Nordemann Publishing Co., New York. $4.15.) H. Gulden 6. (paper); H. Gulden 7.50 (cloth). 10½ x 7¼; xx + 371; 1938.

The author argues for the "continuity" theory of the origin of life, reasoning at length from biology, morphology, ontogeny, paleontology, stratigraphy, biogeography, and paleoclimatology. According to his view living matter first originated from inorganic substances about 1500 million years ago and the different forms of life developed rapidly and phylogenetically.

The bibliography includes 235 titles. There is no index.

FOSSIL ANTHROPOIDS OF THE YALE-CAMBRIDGE INDIA EXPEDITION OF 1935. *Carnegie Institution of Washington Publication No. 495.*

By William K. Gregory, Milo Hellman, and G. Edward Lewis. Carnegie Institution of Washington, D. C. $1.00 (paper); $1.25 (cloth). 10 x 6¾; 27 + [1] + 8 plates; 1938 (paper).

Specimens of fossil ape teeth and parts of jaws secured by the Yale-Cambridge India Expedition have aided the authors in tracing the phylogenetic development of these early simians. All the specimens collected are described in the text, and eight plates of photographs supplement these descriptions. The authors conclude that the extinct anthropoid apes ranged over an enormous area, that the group as a whole was exceedingly variable, and that the Siwalik genus *Ramapithecus* and the South African genus *Australopithecus*, while still simian by definition, were almost at the human threshold.

GENETICS

THE GENETICS OF SCHIZOPHRENIA. *A Study of Heredity and Reproduction in the Families of 1,087 Schizophrenics.*

By Franz J. Kallmann. With the Assistance of Senta Jonas Rypins, and with an Introduction by Nolan D. C. Lewis. J. J. Augustin, New York. $5.00. 9⅝ x 6½; xvi + 291; 1938.

This thorough, factual study of genetic factors in the schizophrenic psychosis is based on 1,087 schizophrenic patients admitted to the Berlin-Herzberge Hospital between 1893 and 1902, 3,279 parents, husbands and wives of patients, 3,384 direct descendants, 3,920 siblings and half-siblings and 2,194 nephews and nieces. The patient material was divided into the four diagnostic categories: hebephrenic, catatonic, paranoid and simple, the two former divisions being grouped as "nuclear" schizophrenia and the two latter as "peripheral" schizophrenia. The nuclear group was found to have a lower fertility and a higher incidence of taint among their descendants than the peripheral group.

The problem of eugenic prophylaxis is considered in a practical way and the conclusion reached that sterilization of schizophrenic patients is an unjustified and inadequate means to the desired end of decreasing the incidence of schizophrenia to a significant extent in succeeding generations. The author feels that the facts fully support the importance of hereditary predisposition for the development of the schizophrenic psychosis, finding that it appears as a recessive trait and that the majority of cases originate through heterozygotic taint-carriers in the patient's collateral lines. The eugenic procedure recommended by the author, namely wide-spread limitation of marriage and propagation in all schizophrenic symptom-carriers at the beginning of their reproductive period, and in all heterozygotic taint-carriers and the homozygotic transmitters with masked and latent traits, is, in its entirety, beyond present-day diagnostic acumen. However, a beginning can be made in educating patients, particularly border-line cases who are most apt to marry, against propagating.

The incidence of tuberculosis in this material was investigated and a striking correspondence found between expectation of schizophrenia and mortality from tuberculosis. The results in this respect are so unequivocal that they can only be interpreted as actual gene-coupling of the tendency to schizophrenia and the heredito-constitutional susceptibility to tuberculous infection. It is suggested that the decisive factor in the genesis of schizophrenia and tuberculosis is a hereditary inadequacy of certain tissues, possibly the reticulo-endothelial cell apparatus.

The volume concludes with a glossary of abbreviations and of genetic terms, an index of tables, an index of names, and an excellent bibliography. An important book.

GENETIC RELATIONS OF SOME COLOR FACTORS IN LETTUCE. *United States Department of Agriculture Technical Bulletin No. 620.*

By Ross C. Thompson. Government Printing Office, Washington. 20 cents. 9 x 5¾; 37; 1938 (paper).

Only brief mention can be made of some of the findings of this study:

> The genetics of the inheritance of anthocyanin pigment in the leaves of lettuce was studied in progenies from 16 crosses involving 9 different homozygous genotypes. Seven genes were found to be necessary to account for all of the segregations obtained in the F_2 and F_3 progenies.
>
> Three genes, *Rr'r*, form a multiple allelomorphic series controlling the intensity and pattern. The presence or absence of anthocyanin was found to be controlled by two complementary factor pairs, *Cc* and *Tt*.
>
> The multiple allelomorphic series *Rr'r* and the allelomorphs *Cc* showed linkage with 36 percent of recombinations.

In the text are illustrations and tables and the work concludes with a list of 29 titles.

NEUE GESICHTSPUNKTE IN DER VERERBUNG. *By August Bier. Verlag von Julius Springer, Berlin.* RM. 3.60. 7¼ x 4¾; [4] + 70; 1938.

In the journal *Züchter* the author, a physician, had recently published some articles on his success in producing the blue lupine (*Lupinus angustifolius*) and the perennial lupine (*Lupinus polyphyllus*) from seeds of the annual *Lupinus luteus*. These received some adverse comment, so in this book Bier describes his experiments, with seeds of known origin, in greater detail and answers some of the objections. This new method of inheritance (the exact mechanism is not known) he has designated by the term "transmutation." He includes also in this book some discussion on the reversion of domesticated plants and animals to the wild type when given the opportunity. This work is well documented, but there is no index.

THE GENETICS OF THE PIG. *Reprinted from Bibliographica Genetica XII.*

By A. D. Buchanan Smith, O. J. Robison and D. M. Bryant. Martinus Nijhoff, The Hague. Gld. 8. 9½ x 6¼; 160; 1938 (paper).

This paper, issued from the Institute of Animal Genetics of the University of Edinburgh, discusses the color, hair and skin, physiological characters, disease resistance, mental traits, sex, abnormalities and defects, and anatomy and conformation of the pig, in the first 82 pages. Then follow sections on the productive qualities (20 pp.) and methods of improvement of the breeds (15 pp.). Both the geneticist and the practical breeder will find much of interest in these pages and the lengthy literature list (27 pp.) invaluable. A group of illustrations and subject and author indexes conclude the study.

GENERAL BIOLOGY

METHODS AND MATERIALS FOR TEACHING BIOLOGICAL SCIENCES. *A Text and Source Book for Teachers in Training and in Service. First Edition.*

By David F. Miller and Glenn W. Blaydes. McGraw-Hill Book Company, Inc., New York. $3.50. 9 x 6; xii + 435; 1938.

This excellent text and source book for teachers and teachers in training has been written in direct response to a need frequently expressed by teachers of and teachers in training for elementary courses in the biological sciences. The four aims of the text are: (1) to encourage teachers to abandon the all too common method of book-teaching with little use of materials; (2) to assist the teacher in locating, securing, or culturing living materials at little expense; (3) to suggest how these materials may be used in classroom demonstrations and student projects and to explain how to set up simple homemade and inexpensive apparatus; (4) to foster through suggestion the use of the problem and project method so that the student will get practice in using his biological information in the understanding of principles and the application of these principles in his daily life.

The work covers particularly those questions frequently asked by student teachers on the problems of biology teaching. There is a general and representative bibliography.

LIFE IN AN AIR CASTLE. *Nature Studies in the Tropics.*

By Frank M. Chapman. Drawings by Francis L. Jaques. D. Appleton-Century Co., New York and London. $3.00. 8⅝ x 5¾; xii +250 + 31 plates; 1938.

This is a completely diverting book—it is the kind one wishes to share immediately with a congenial friend. Barro Colorado is the largest island in Gatun Lake, and the Institute for Research in Tropical America has here carried on its studies of flora and fauna since 1923. Dr. Chapman settles down each year (1938 being his twelfth season) in this natural laboratory to a period of intensive, but patient and leisurely observation of his strange neighbors which include many rarely seen tropical birds, monkeys, coatis, opossums, kinkajous, peccaries, turkey buzzards, and parrots in their jungle habitats. He describes the songs and calls of the birds in the trees near his balcony, and also the characteristics of the birds of the tropical waters. *Life in an Air Castle* is a sequel to the naturalist's earlier volume entitled *My Tropical Air Castle.* These two books constitute a remarkable record and will delight the layman as well as the bird lover and botanist.

The text is illustrated with photographs by the author, and drawings by Francis L. Jaques. There is a very helpful list of reference books, as well as a list of the birds of Barro Colorado, and a satisfactory index of five and a half pages.

BIG FLEAS HAVE LITTLE FLEAS *or Who's Who Among the Protozoa.*

By Robert Hegner. Williams & Wilkins Company, Baltimore. $3.00. 10 x 6⅝; vi + 285; 1938.

Growing out of a series of six lectures delivered before a general audience (Messenger Lectures, Cornell University, 1937), this book is distinguished among books of its kind. Indeed, in the manner of its presentation, it is unique. Combining scientific exactness with the attractiveness and readability of "Ferdinand," Hegner introduces the protozoa in a way which will appeal at once to the protozoologist, to the young student who is just discovering microscopical life, and to anyone else who is curious about living things. Taxonomy becomes the "Parade of the little millions," while the control of malaria is dealt with in a chapter called "Conquistadors." Between these topics one finds discussions of typical life cycles, parasitism, the evolution of new forms, the effect of diet on man's "inner life," etc., told as the adventures of that mighty hunter, the protozoologist, armed with his trusty microscope.

Hegner's book is not a textbook, yet it seems destined to be used as a text in many a classroom. It presents first-hand knowledge in a lively, conversational style, both in prose and in verse, and is illustrated with good photographs and drawings, serious and otherwise.

WILD NATURE IN AUSTRALIA. *Wonder Animals and Birds.*

By Charles Barrett. Robertson and Mullens, Melbourne. 2s. 6d. 9½ x 7¼; 56; 1938 (paper).

Australia is indisputably the land of marvels; a fact which is amply attested by this fascinating little book. Why evolution should have singled out the lone island continent of Australia to go on a spree in ages past is still a mystery to the most learned naturalists. Barrett has devoted much of his life to a study of the natural wonders of Australia, and has attempted in many ways to create in man an appreciation of these wonders to the end that they may be preserved in their natural state for all posterity. His book is a delightful pictorial record of some two dozen animals and plants native to Australia, together with the scientific name and characteristic habits of each form. The following are some of the forms described: the lyre, the bower and mound-building birds, fairy penguins, the kookaburra, the emu and the cassowary, platypus, echidna, giant earthworms (12 feet long in rare cases), wombats, tree-ferns; and seabird "cities" and white ant citadels.

ADVENTURES WITH LIVING THINGS. *A General Biology.*

By Elsbeth Kroeber and Walter H. Wolf. D. C. Heath and Co., Boston and New York. $1.96. 8 x 5⅜; xiii + 798; 1938.

Fundamental biological concepts are well brought out in this text for secondary school students. The ideas are clearly presented in such a manner that the language and subject matter increases in scope and difficulty along with the students' growing ability to comprehend. The first part of the volume introduces the phyla and classes of plants and animals. The second section deals with metabolism, behavior, and reproduction; the third treats of biological generalizations involving similarity, variability, heredity, environment, and evolution. Questions and experiments are suggested to supplement the reading.

Interestingly written, the book contains many brief sketches of the lives and noteworthy experiments of emminent biologists.

PHYSICAL GEOGRAPHY AND GEOLOGY.

By L. Dudley Stamp. Longmans, Green and Co., New York and London. $1.75. 7¼ x 5; vii + 256; 1938.

A good impression of methods of topographical formation could be obtained by glancing at the photographs in this book. These pictures are supplemented by numerous drawings and climatic maps. Most of the examples used were known to the author personally, but what has been a gain to the reader in this respect has been a loss in the confinement of the material almost exclusively to the British Isles and India. Hence the work is far more suitable for English students than for those of the United States or Canada.

An attempt to show relationships between geology and biology falls short of what the biologist would like, especially in that section dealing with the history of the earth. However, this does not impair the value of the book as a physical geography text.

PROCEEDINGS AND TRANSACTIONS OF THE LIVERPOOL BIOLOGICAL SOCIETY, *Volume 51. Session 1937–1938.*

Edited by R. J. Daniel, with the co-operation of S. T. Burfield and W. S. Laverock. University Press of Liverpool. 1 Guinea. 8½ x 5⅜; ix + [3] + 70; 1938.

Reports on the following investigations are given in the second part of volume 51 of these "Proceedings": (1) The fauna of fixed and floating structures in the Mersey Estuary and Liverpool Bay, by James H. Frasier (pp. 1–21). This paper discusses the polution, silt and debris in the water, and the varying salinity in relation to their detrimental effects on the fauna present. (2) The Manx Herring Shoals, by W. C. Smith (pp. 22–75). In this fishing region, three areas can be distinguished with characteristic classes of fish in each: an inshore ground, divided into a northern section (range of size of fish 22–26 cm., mode 23 cm.), and a southern section (24–28 cm., mode 26 cm.), and an offshore ground (26–29 cm., mode 28 cm.). The statistical material is arranged in 13 tables.

MANUEL CRITIQUE DE BIOLOGIE.

By J. Lefèvre. Masson et Cie, Paris. 190 francs. 10 x 6⅝; 1048; 1938 (paper).

This weighty tome is divided into five books, as follows: (1) the cell in general—cytology; (2) cells functionally differentiated—histophysiology; (3) nutritional and metabolic functions; (4) neural and sensory functions; (5) bioenergy—vital heat and the animal machine. It is based on the author's class lectures at the Laboratory of Bioenergetics, Paris, and emphasizes the necessity of developing critical faculties among readers and pupils in order that they may orient themselves in the chaos of contradictory theories and be prevented from taking as facts everything they see in "scientific" movies.

There is an index but no bibliography.

PHYTOPLANKTON AND THE HERRING. *Part III. Distribution of Phosphate in 1934–1936. Fishery Investigations, Series II, Volume 16, Number 3.*

By Michael Graham. H. M. Stationery Office, London. 2s. (Obtainable in North America from British Library of Information, New York). 60 cents. 10¾ x 7; 30; 1938 (paper).

A report of the survey of plankton and hydrology over the greater part of the southern North Sea during the summer and autumn of 1934, 1935 and 1936. Charts (on transparent paper) showing the phosphate concentration at one meter's depth accompany charts (by Savage and Wimpenny) showing the diatom (*Rhizosolenia*) patch. The author discusses the factors which favored the vast diatom concentration of 1934 and caused its more recent decline. Maps and figures accompany the report, also a reference list. The last four pages in the bulletin give a list of scientific publications on sea fishery investigations issued by the Ministry of Agriculture and Fisheries.

SEVENTY-FIVE YEARS. *A History of The Buffalo Society of Natural Sciences 1861–1936. Volume XVIII.*

The Buffalo Society of Natural Sciences, Buffalo. $2.00. 9¼ x 6¼; 204 + 53 plates; 1938.

This volume, published in celebration of the Buffalo Society of Natural Sciences' seventy-fifth anniversary and written by ten members of its staff, contains numerous chapters on the museum's special features and collections, as well as a history of the society and its plans for the future.

HUMAN BIOLOGY

RESEARCH MEMORANDUM ON POPULATION REDISTRIBUTION WITHIN THE UNITED STATES. *Bulletin 42.*

By Rupert B. Vance. Social Science Research Council, 230 Park Ave., New York. $1.00. 9 x 6; xiv + 134; 1938 (paper).

RESEARCH MEMORANDUM ON MIGRATION DIFFERENTIALS. *A Report of the Committee on Migration Differentials. Bulletin 43. By Dorothy S. Thomas, with contributions by Rudolf Heberle, E. P. Hutchinson, Eleanor C. Isbell, Fritz Meyer and Svend Riemer. Social Science Research Council, 230 Park Ave., New York.* $2.50 (cloth); $2.00 (paper). 9 x 6; xiv + 423; 1938.

CITYWARD MIGRATION: SWEDISH DATA. *By Jane Moore. University of Chicago Press, Chicago.* $2.00. 9 x 6; xix + 140; 1938.

The events of recent years resulting from the seemingly abrupt changes in the material well-being of the people of this country have served to focus more than ever the attention of students of social sciences on the need for adequate information about internal migratory movements. The two memoranda published under the aegis of the Social Science Research Council are a by-product of the increase of interest in the subject. Both of them contain critical discussions of the investigations done on the subject and outlines of feasible future research. In Bulletin 42, Vance examines the problem from the standpoint of the relation of economic opportunity to differential population increase. First he outlines the several aspects of the problem relating to variations in economic opportunity according to the regions of the country and proceeds then to consider differential increase of population, changes

in employment opportunity and capacity, and labor mobility.

Bulletin 43 is concerned with the problem from the standpoint of the demographic traits of the migrant as compared to the stable population. In addition to a survey of some of the information on age, sex, civil status, physical and mental health, and occupation of the migrant, this memorandum contains seven appendices. In these, the author and others present annotated references to English, America, and German studies, notes on German and Swedish statistics and on the methodology of fact-finding.

One of the questions about which both writers are greatly concerned regards the movement of population from rural to urban areas. A contribution on one aspect of this query is made by Jane Moore in her study based on the 1930 Swedish census data. The inquiry has for its purpose to determine the characteristics of the community of birth and of previous residence of a selected portion of the "in-migrant" Stockholm population. The results of the analysis bearing on this point are presented in the first section of the monograph. The author finds that in the sample examined the relative proportion of persons coming to Stockholm directly from rural and agricultural areas is less than that of migrants who, although born in such areas, have first moved to towns and mixed industrial and agricultural areas. In turn, the latter constitute a relative number inferior to the migrants who were actually born in urban places. In the second section are recorded the data on the education, civil status, and types of occupation of the group of migrants studied. The general conclusion reached by the author is that the economic factor alone is not sufficient to explain migratory movements but that there is besides a tendency to migrate to and from closely resembling types of communities.

Moore's study, while not conclusive, brings out one of the features about migration that neither Vance nor Thomas has taken into sufficient account. It is that migration, whether internal or otherwise is not merely an economic phenomenon but is also a psychobiological one. It would seem therefore that, as for population problems in general, the problem of migration will be sufficiently clarified only if due importance is given to its biological aspects.

NEW HORIZONS FOR THE FAMILY.

By Una Bernard Sait. The Macmillan Co., New York. $4.00. 9¼ x 6¼; xiii + 772; 1938.

The author of this treatise is a professor of philosophy and so it is not surprising to find that the main purpose of this work is "to develop a broad philosophy of the family" and that the subject is presented on such a large canvas. The first part of the book is historical and discusses the status of the family in terms of social organization, religion, economics, sex, and education. The second part is on the contemporary family and is concerned mainly with the problems of education and welfare of children, the status of women, birth-control, and marital conflicts. The third and last part regards the problems of homemaking, financial and otherwise. The most striking features of the book are the great erudition demonstrated by the author and her eloquent style. She recognizes that this is a period in which the traditional inter- and intra-familial relationship patterns are undergoing alteration and she hopes that the future will see the development of the cooperative family. So far as can be understood this means the application of Dewey's type of liberal philosophy to intra-marital relations. Anyhow, the author hopefully envisions the future in the following terms and in her characteristic style:

> In a family which is genuinely coöperative, the relationships between father, mother, and their children may once again become a radiating source of sympathy and understanding, in widening circles of social relationship. For the *care of life*, which in all ages has been the central preoccupation of women, is now recognized as the most vital concern of society. The spirit of motherliness, utterly opposed to force and violence, is found invaluable in human affairs. As more women become emancipated from ignorance, idleness, and the bonds of tradition, we may hope for fuller integration of scientific knowledge in the interests of human relationships, and for the shaping of new instrumentalities of social control.

But, as the spirit of motherliness is needed in the life of the world, so is there need for a fuller participation of men in family life—for a more intensive fatherliness. Manliness with its emphasis on protective strength, reliability, and courage is the correlative of womanliness, from which all trace of immature dependence has gone, but where the emphasis is still upon the qualities conducive to the care of life. Where manly men and womanly women also become developed human beings, the coöperative family will more fully emerge as the prevailing pattern of family life. Only then will its consequences for individual happiness and social well-being become apparent.

AFRICA'S GOD. *X. Conclusion. Anthropological Series of the Boston College Graduate School, Vol. III, No. 3.*

By Joseph J. Williams, S.J. Boston College Press, Chestnut Hill, Mass. $1.00. 9¾ x 6½; 46; 1938 (paper).

Part X summarizes briefly the data included in Dr. Williams' nine previous publications which have been reviewed in earlier numbers of this journal and have dealt with religious beliefs in Africa in the following geographical sequence: (1) Gold Coast and its hinterland, (2) Dahomey, (3) Nigeria, (4) French West Africa, (5) Congo and Angola, (6) Uganda, (7) East Africa, (8) Rhodesia, and (9) South Africa. The conclusions reached concerning these beliefs are that the religion of Africa is at present or has been at some time in the past monotheistic and that Hebraic contacts have played an important part in the religious beliefs and customs of the African tribes. Though the belief in a Supreme Being has, in many cases, been overshadowed by a heterogeneous and often incoherent animism, nevertheless there is a clearly defined monotheistic concept.

The author states that, in opposition to the theory of the classical evolutionists that African tribal religion has gradually risen from polytheism to monotheism, his own findings point rather to "a general retrogression in matters of religion and even where tribes have been polytheistic in recent years, there is often a clear indication of monotheistic belief in earlier days." Concerning the subject of Hebraic contacts, the author writes that "The presence of Hebrewisms throughout the length and breadth of Africa leads one to suspect that the monotheistic cults of more recent times are due to an infiltration of Hebraic stock at an earlier stage in the development of the African Tribes."

Part X, like the previous numbers, includes many specific examples of Hebraic customs to be found in the various tribes, interesting facts concerning the different cults of worship, such as ancestor worship, demonology, ophiolatry (serpent worship), etc. and many other bits of information that could only be observed by people living in long and close contact with the peoples of Africa.

Following Dr. Williams' research there is an article on the Ghassulian flint industry in Tell 3, level IV, of Teleilat Ghassul by J. W. Murphy, S.J., who, in the last issue, reported on the pottery findings in this same ancient site.

DAHOMEY: *An Ancient West African Kingdom. In Two Volumes.*

By Melville J. Herskovits. J. J. Augustin, New York. $12.00. 9½ x 6¼; Vol. I, xxi + [1] + 402; Vol. II, xiv + [2] + 407; 101 plates; 1938.

As the author well emphasizes, the study of native life in Dahomey presents a number of points of great interest and importance. In the first place, the social behavior pattern of the people and the political organization of the country (aside from very recent changes) represent a stage of social evolution unique among primitive African peoples. In addition, the civilization of Dahomey until a few years ago had been probably less affected than that of any other African territory by contact with the whites. It can be assumed then that a better understanding of the social behavior of other primitive peoples can be acquired from a study of Dahomey. With this view in mind and also in the hope of clarifying certain questions on the original social background of the American Negro, the author presents here the results of his personal visits to that country. He begins by examining the economic life of this group, that is to say, the production and distribution of goods and wealth, taxation and other

group regulations involved in the business of earning a living. There follow chapters on social organization that contain accounts of the kinship relations with emphasis on the highly complicated system of sib organization and the cult of the ancestors. Then, there are chapters concerning social behavior in relation to all phases of the individual development from birth through puberty, marriage and death. In the second volume, the author treats of the political organization and gives a most thorough and explicit account of the religious aspects of Dahomean culture. The final chapters deal with the art-forms developed in that country. The book contains also a sufficient if not exhaustive bibliography and there are a few interesting illustrations of the natives and some beautiful reproductions of local art. The majority of the information reported consists of first-hand observations and these have been well integrated with the more important previous studies on the subject. In this respect the one objection that could be raised is to the tendency to quote verbatim and at too great length passages from earlier writers. Except for such insertions, the book is written in a style that is straightforward and clear. With this work, Herskovits has made a definitive and lasting contribution to anthropology and ethnology.

FRANCE FACES DEPOPULATION.

By Joseph J. Spengler. Duke University Press, Durham, North Carolina. $3.00. 9 x 5¾; xi + 313; 1938.

As early as 1325 France attained the demographic hegemony of Europe; about 1650 France reached her period of relative demographic dominance; in 1800 France had a population exceeded only by that of Russia; prior to and especially after 1850 the population of France grew less rapidly than that of other European lands and in 1850 France found herself stripped of the demographic hegemony of Europe. Moreover, "low natality and not high mortality was and is primarily responsible for the steady diminution in the rate of population growth in France."

In this monograph, the author traces the history of population growth in France, the changes in the geographical and occupational composition of the population, the history of natural increase during the years 1650–1935, the changes in differential natality and fertility and the history of the depopulationist fears which were expressed as early as the fourteenth and fifteenth centuries but were never so intensive as the alarm at the post-1800 decline.

The author also outlines the French explanations of the causes of the decline in natality and the policies and measures taken by the government to counterbalance the effects of low natality and to promote natural increase. Finally, the author analyzes the probable consequences of French population trends and appraises the measures for the promotion of population growth. In this last part, the author deals with the relationship of population growth and the economic welfare of the individual and the masses.

COBBERS. *A Personal Record of a Journey from Essex, in England, to Australia, Tasmania and some of the Reefs and Islands in the Coral Sea made in the Years 1930, 1931 and 1932. New Edition.*

By Thomas Wood. Oxford University Press, London and New York. $2.50. 7¼ x 4¼; xv + 288; 1938.

The genuinely friendly character of the Australian people prompted the title of this book (cobber = Australian slang for companion or mate). The author states in the preface that "this is not a guide book," nevertheless, those who are contemplating emigrating to Australia or visiting the continent should read it. In so limited a space we can only give brief extracts of some of the general comments offered.

Your bush, your wheat belt, your mulga scrub, your saltbush plain are great tracts of country, every one a matter for days in a car. You cannot give a glance and look for something fresh round the corner, for round the corner is just the same as where you are now. The mountains and the foothills, the tropical north, and, above all, Tasmania, change quicker: offer, like the English scene, better foreground country; but Australia as a whole gives bulk, not samples.

As with country, so with climate. "It never rains but it pours." . . . And it does not pour often enough. Floods are bad, but they are only one of the farmer's troubles. Drought is worse.

The easy optimism which the author found generally throughout Australia has, in his belief, its origin in (a) the climate, which is "mostly gloriously sunny and warm"; (b) the "give-it-a-go" attitude "which results in many jobs left unfinished" and (c)

this country of great distances does not necessarily breed great minds. It tends, on the contrary, to breed narrow ones. Here is another generalization far away from the whole truth, though near enough to a part of it. I have met throughout Australia men who were as well-informed and as imaginative as any one could wish for; but they are not typical. A great many of their countrymen made me feel that I was talking to precociously alert and self-satisfied children; and that I was an old, old man.

Australia is said to be "ninety-eight per cent British" yet the author found it unexpectedly cosmopolitan. An interesting trip was made to Phillip Island (50 miles from Melbourne)—a reserve for seals, penguins, mutton birds and the very charming native bears, the koalas.

The volume has a useful index. We wish that a map had been included.

HEALTH AND UNEMPLOYMENT. *Some Studies of Their Relationships. McGill Social Research Series: No. 7.*

By Leonard C. Marsh. In Collaboration with A. Grant Fleming and C. F. Blackler. Oxford University Press, New York. $3.00. 8½ x 5⅜; xxv + 243; 1938.

That there are direct relationships between the statistics of employment and of the prevalence and duration of illness, the authors of this volume do not doubt, though they expressly point out that this is an assumption unverified by any sufficiently extensive study. Yet most readers will agree that the following statements are strong probabilities:

When the family income falls below a certain level, the standard of living declines rapidly. A small sum to spend on food usually means lack of fruit, fresh vegetables, milk and fats. Inadequate footwear and clothing increases the liability to colds and other ailments. Families move to low-rent areas or 'double-up' to economize on rents, resulting in overcrowding, which is one of the worst evils of bad housing so far as physical health is concerned. Perhaps the worst sufferers are the 'new poor,' for they lack experience in living to the best advantage at low economic levels, and, in addition, their mental health is seriously jeopardized by the severe crisis through which they are struggling to make an adjustment. In the face of widespread unemployment, members of the lowest wage classes particularly find themselves without the means for health expenditures, apart altogether from the bare necessities of life.

This book does not pretend to be a complete survey of health conditions among the unemployed. It is but one series of detailed studies, based on Canadian surveys, and involving both adult and immature persons, which presents evidence in support of the statements quoted above, and which ends with a discussion of medical provision for the unemployed. The authors anticipated that their studies would "soon be superseded by wider health surveys or governmental statistical enquiries," but this has not been the case, hence the present studies are published on their own account, "in spite of their limitations."

PICTURE-WRITING OF TEXAS INDIANS. *The University of Texas Publication, No. 3809, March 1, 1938. Anthropological Papers, Volume II. Bureau of Research in the Social Sciences Study No. 27.*

By A. T. Jackson. The University of Texas, Austin. Free. 10⅛ x 6¾; xxv + 490; 1938 (paper).

Just exactly what the early American Indian was trying to express when he painted or carved the strange figures which occupy the walls of numerous rocks, cliffs and caves of our western states, we shall probably never know. A popular theory has had it that the picture writing represented nothing more than the activities of an idle pastime. Jackson's study of the picture writing of the Texas Indians proves this theory entirely fallacious, and points out that the relics of Indian art are of enormous value in reaching a sociological or a psychological interpretation of early American cultures. The majority of materials for this study were found in about 30 counties

which make up the southwest corner of the state of Texas. It is interesting to note that the picture writings are not evenly distributed but according to the topography and geography of the land. Just the right surfaces have been selected in each case for the pictographs and petroglyphs, and the area where such surfaces are absent are devoid of any of the art. The point in emphasis throughout the volume seems to be that unless the present destruction of valuable sites of prehistoric art by vandalism is arrested, another decade or two will see the complete obliteration of much of the worthwhile picture writing, and with it the vanishing of much valuable history concerning early American man.

The text contains 324 maps showing the distribution of various forms of picture writing, (283 photographic figures), a bibliography of some 140 titles, and an index.

MARGARET SANGER, *An Autobiography*. *By Margaret Sanger. W. W. Norton and Co., New York.* $3.50. 9½ x 6¼; 504; 1938.

Margaret Sanger's own account of her busy career and the history of birth control is here given in a lengthy detail which is neither tedious nor monotonous. With a skilled pen, a sense of both the humorous and the tragic, and a keen sympathy for those with whom she comes in contact, this crusader relates the happenings of her turbulent life from early childhood. Even those well acquainted with her fight for birth control should find new interest in the reminiscences of the author's early days and in her vivid description of her unusual family and childhood in Corning, New York, where as one of eleven children it was early impressed upon her that large families and poverty go hand in hand.

The story of Mrs. Sanger's ceaseless crusading for birth control despite her tubercular condition, her battles with the government and her subsequent imprisonment in the State of New York for the principles for which she fought, are well known. But added to this her autobiography contains many fascinating travel notes of the countries into which she was led by her research. She writes of starving post-war Germany, of over-populated Japan, of the wretchedness of China and India, of Russia, Holland, England and Ireland with a clarity which stimulates the imagination. The descriptions of the people she has met in these wanderings also lighten these pages with amusing character sketches, for in this volume Margaret Sanger gives us intimate glimpses into the lives of such figures as Havelock Ellis, H. G. Wells, Professor Hu-shih, Gandhi and many others.

BROWN SOUTH AFRICA. *By C. Ziervogel. Maskew Miller, Ltd., Cape Town.* 7¼ x 4¾; 95 + [1]; [1937?]. This book is published, as the author states in the preface, "at the request of many friends and by the crying need for a book about the coloured people by a coloured man". It is a study of the conditions in South Africa after the coming of the Dutch and deals with the subsequent vicissitudes experienced by the non-Europeans following this arrival.

In order to show more clearly what is meant by Brown South Africa, the following summary of the history as presented by the author is in order. On April 6th, 1652, Johan von Riebeeck and his small crew of men arrived in Table Bay, South Africa, to set up a refreshment station for the Dutch East India Company. Their arrival marked the beginning of Brown South Africa and of White South Africa. The Dutch found two peoples in South Africa—the Hottentots and the Bushmen. The Company had ordered these Dutch settlers to placate the natives and placation was carried to the point of intermarriage. In addition, slaves from Madagascar, Mozambique, and Malay were imported to help the settlers, and the subsequent relations of these slaves with the half-castes and the whites appreciably swelled the already increasing numbers of "hybrid browns" or the so-called colored population of South Africa.

The author discusses in this book the

economic, political, and educational history and the national welfare of colored people in South Africa under Dutch and English rule. The picture that he draws of colored life in South Africa is not an attractive one, and the following quotation clearly defines the author's feelings concerning the lowly life of his people: "The non-European of the twentieth century resents the social injustice meted out to him, and is determined to take his place in the social life of the land of his fathers."

CINQUANTE SIÈCLES D'ÉVOLUTION ETHNIQUE AUTOUR DE LA MER NOIRE. *Études d'Ethnographie, de Sociologie et d'Ethnologie, Tome I.*

By Alexandre Baschmakoff. Paul Geuthner, Paris. 40 francs. $9\frac{1}{4}$ x $6\frac{3}{8}$; x + 177 + [3] + 2 plates; 1937 (paper).

One of the controversial points in ethnology concerns the importance to be given to linguistics as a method of study of ethnic evolution. Many eminent students of the subject believe that it has little value but the so-called Japhetic school which has developed in the last thirty years from the work of Marr in Russia takes the position that for the purpose of prehistoric investigations linguistics has equal value with anthropology and archaeology. According to this viewpoint, by appropriate linguistic analysis it is possible to reconstruct the historical development of a region and the purpose of this book is to illustrate the application of the general method in relation to the history of the peoples who have inhabited the Caucasus, Southern Russia, and Asia Minor. The study is introduced by a consideration of the ethnic stock of the peoples that today inhabit these regions. The author proceeds then to a discussion of the history of the Cimmerii and Iranian Scyths, the origin of the Khazars and that of the Karaites and of the pseudo-Tatars of Yalta. One of the most important conclusions reached by the author is that the Karaites are the direct and relatively unmixed descendants of the ancient Tauri and that to a lesser degree the pseudo-Tatars of Yalta may also be considered as the only remnants of the aborigines of the region. The arguments advanced by the author are presented clearly but in a very condensed form. No mention is made of the principles of the method involved and the evidence bearing on the conclusions is not as yet sufficient.

GENERAL ANTHROPOLOGY.

Edited by Franz Boas. With Contributions by Ruth Benedict, Franz Boas, Ruth Bunzel, Julius E. Lips, Robert H. Lowrie, James H. McGregor, N. C. Nelson, Gladys A. Reichard. D. C. Heath and Co., Boston. $4.00. $8\frac{3}{4}$ x $5\frac{3}{4}$; xi + 718; 1938.

The general trend in the writing of many anthropology texts has been that of developing a rather stereotyped discussion of ethnology, and then dropping the subject as though the entire field had been covered. The excellence of the present volume is the result of the thorough and careful coordination of ethnology with the other principle aspects of the subject; namely, paleontology, archaeology, linguistics, physical anthropology, and biology. Many chapters on the various subjects relative to general anthropology have been contributed by specialists in the particular fields, but even this fact would not have been such an important asset to the volume if it were not for the careful coordinating and editing of the materials by Dr. Boas.

The subject has been presented so graphically, and illustrated so aptly that the beginning student in anthropology should have no difficulty in gaining a firm background in the subject, even with a minimum of effort. The extensive list of bibliographic references accompanying each chapter makes the volume exceptionally valuable for the reference shelf.

LABOR IN THE UNITED STATES. *Basic Statistics for Social Security. A Report Prepared for the Committee on Social Security. By W. S. Woytinsky. Social Science Research Council, 230 Park Ave., New York.* $3.50. 9 x 6; xxii + 333; 1938.

In this country, the recent enactment of

laws relating to unemployment compensation and old age insurance has emphasized the need for still another type of classification of occupations—one that would give some precise information about the number of persons subject to these laws and the amount of money involved. The Committee on Social Security of the Social Science Research Council has, for this reason, undertaken to revise the 1930 census data on occupations so as to give an adequate foundation of facts to future discussions of the subject. The project was assigned to Dr. Woytinsky whose principal task has been to reassort the census data so as to arrive at a classification of employees according to industries rather than type of occupation and to achieve also the required segregation of employers and employees. The author has successfully and effectively carried out the project and in this volume presents his results. The first section of the book deals with the supply of labor, type of work, race, age, sex, and duration of employment. The second part discusses the demand for labor and regards the distribution, type and size of industrial establishments. Besides rearranging the census data the author also proceeds to estimate the conditions of the future. Of course, such extrapolation must be accepted with due caution but the conclusions reached are interesting. The methods employed in the redistribution of the data as well as the pertinent original figures are presented in sufficient detail and, although by this means the picture of employment is not substantially altered, the resulting classification deserves the attention of the students of the subject as well as of those charged with the forthcoming census.

ACCULTURATION. *The Study of Culture Contact.*

By Melville J. Herskovits. J. J. Augustin, New York. $2.00. 9 x 6½; 155; 1938.

This book deals with the methodology involved in the study of acculturation and stresses the necessity of historic controls and scientific objectivity in such studies. After defining the term acculturation and stating the various and conflicting meanings that the word has been given, the author proceeds to discuss field methods employed in acculturation studies. Excerpts from studies on acculturated primitive peoples are quoted and evaluated in order to illustrate the practical method of approach to the analysis of the processes. In addition to full-length portraits of acculturated peoples, the affects of culture contacts on such restricted phases of cultures as religion, folklore, music, and linguistics are considered. The author also discusses available works of fiction dealing with problems of acculturation, and lastly, he gives some suggestions for future research on these problems, pointing out some areas in the world where particularly fruitful studies could be made, and dwelling briefly on the importance of studies on human personality from the point of view of the interplay between personality and culture.

LA PRÉHISTOIRE.

By A. Vayson de Pradenne. Armand Colin, Paris. 15 francs (paper); 17 francs 50 (cloth). 6¾ x 4½; 224; 1938.

This excellent treatise on prehistory is concerned with the methods, materials, and sources of error in present-day studies of the eras of cultural development antedating all written records. M. Pradenne's definition of prehistory points to the fact that in spite of the advanced stages of civilization over the greater part of the world today, there exist contemporary prehistoric races. The methods for studying early civilizations are classified under the general heads of (1) geological, (2) archaeological, and (3) the study of human remains, and the manifestations of human activities.

The text contains detailed descriptions of the fundamental discoveries in the well-known stations of western Europe, Africa, Asia, the Pacific Islands, and America. Throughout the volume there is a note of warning that the method of handling materials and the interpretation of observations are just as important in discussing prehistory as the authenticity of the discoveries.

AN ARCHAEOLOGICAL SURVEY OF THE NORRIS BASIN IN EASTERN TENNESSEE. *Smithsonian Institution, Bureau of American Ethnology, Bulletin 118.*

By William S. Webb. Government Printing Office, Washington. $1.00. $9\frac{1}{8}$ x $5\frac{5}{8}$; xv + 398 + 152 plates; 1938 (paper).

An archeological survey of the areas to be inundated in the Tennessee Valley revealed 23 sites showing definite evidence of prehistoric occupation. On these sites were found 20 earth mounds, 9 stone mounds, 4 village sites and 7 caves. The remains of 50 wooden structures were uncovered, 20 of which were thought to have been dwellings and 34 of which have been designated as "town houses." A study of the skeletal remains shows the people to have been a little above medium height with brachycephalic or mesocephalic skulls, somewhat deformed because of the binding of the head in infancy. In only one site (No. 20) were the individuals distinctly dolichocephalic in character with heads long and narrow, high dome, and no artificial deformation. Thirty-nine charts, 152 plates, a list of references and an index complete the volume.

THE PEOPLING OF VIRGINIA.

By R. Bennett Bean. Chapman and Grimes, Boston. $3.00. 8 x $5\frac{1}{4}$; viii + 302 + 7 plates; 1938.

This work is essentially a supplement to the author's monographs on the anthropometric data he obtained by measuring Old Virginians. It is a compendium of the history of the ethnic development of Virginia from the date of its first settlement. In the first section of the book, Bean summarizes the history of the colonization of the state giving the names, national origin, and social position of many of the early settlers. In the second section there are listed for each county the names of the more important first families as well as the frequency distributions of the family names of the inhabitants according to national origin as observed in pre-revolutionary times and at present. The third and last part serves to give a very brief outline of the anthropometric data he obtained. While the book will undoubtedly serve to elucidate further the author's findings on these peoples and will be useful for those interested, it cannot be said to be very exciting. It is far too condensed, having most of the time the characteristics of a telephone directory. Moreover, the author has omitted all discussions regarding the real pertinence of this work to the previous observations.

THE DOCTOR REMEMBERS.

By Sir James Crichton-Browne. Gerald Duckworth and Co., London. 7s. 6d. $7\frac{1}{4}$ x $4\frac{3}{4}$; 308; 1938.

The doctor's life was long—97 years!—and his interests wide. This is the last "bedside anthology" to come from his rich experience. If one likes anecdotes of famous people, they are here; if one likes anecdotes by a Scot about Scots, they are here. And if one is interested in another's thoughts on religion, politics, insanity, the function of the brain, education, and many other things, he will find them here. Even jokes and comic poetry are included.

As a picture of an eminent medical man of Victorian Britain, this book is fine. One can only wish that Sir James had given a little more space to his ideas about the mentally ill and their care (psychiatry was one of his special interests), but for them one may turn to his scientific papers. What was, perhaps, his basic concept, he states thus (p. 39): "Universities and lunatic asylums have this in common, that they are both concerned in promoting mental equilibrium."

MODERN MAYA HOUSES. *A Study of Their Archaeological Significance. Carnegie Institution of Washington Publication No. 502.*

By Robert Wauchope. Carnegie Institution of Washington, D. C. $3.00 (paper); $3.50 (cloth). $11\frac{1}{2}$ x 9; vii + 181 + 37 plates; 1938.

Excavation of house mounds at the ruins of Uaxactun, Guatemala, (1932) made it

clear that very little information, except upon certain features of sub-structures, could be gleaned from excavation without some examination having first been made of modern houses and the way in which they fall to pieces. For this reason the ethnological work for the present study was done chiefly from an archaeological point of view, and is a comprehensive and detailed study of modern Indian house types in the Maya area, undertaken in 1934 with the purpose of collecting data to facilitate interpretation of ancient dwelling cites.

The text which minutely covers every portion of the house from the details of its foundation features to those of its thatched roof, is supplemented by numerous excellent drawings of the houses and the details of their structure. The work, with an index of place names only, has however a substantial list of references and contains an excellent group of some 150 photographs.

DIE ALAMANNEN VON ELGG. (*Kt. Zürich.*) *Eine anthropologische Untersuchung. Dissertation.*

By Walter Trudel. G. Büchi Buchdruckerei, Zürich. 5 Swiss francs. 9¼ x 6¼; 102 + 10 tables + 2 plates; 1938 (paper).

In 1934, 142 graves—about half those on the site—dating from the seventh century A.D. were opened in Elgg, near Zürich. Of these 140 were in a condition usable for anthropological study. The author herein gives measurements and indices of the skulls, scapulae, claviculae, bones of the arms and legs, feet and vertebrae. Although his findings confirm the Nordic origin of the Alamanni, the Elgger group did not manifest a homogeneous type according to anthropological characteristics, especially in cranial indices. Dolicho-, meso-, and brachycephalic types were all found, with the former two predominating. Whether a mixture with foreign elements occurred during their wanderings to the south or only after their settlement among the Celts in Switzerland, the author was not able to conclude from his material. A bibliography and many tables are included.

THE SCIENCE OF SOCIETY. *An Introduction to Sociology.*

By J. Rumney. Gerald Duckworth and Co., London. 3s. 6d. 7¼ x 4¾; 125; 1938.

One cannot expect to fix a car without knowledge of the interrelation of its parts. Just so, the ills of our social system cannot be cured without recourse to a study of the delicate equilibrium that must exist among the institutions comprising it. Rumney's analogy indicates the practical service of sociology as a synoptic science. But in his view repair service is not enough. Sociology has a further obligation to foresee and control the course of social movements. Apropos of these considerations chapters are devoted to the structure of society, political and economic. The chapter on biological sociology concerns itself primarily with racial discrimination and concluding sections give briefly the history of sociology and methods used in its study.

BANTU BELIEFS AND MAGIC *with Particular Reference to the Kikuyu and Kamba Tribes of Kenya Colony; together with some Reflections on East Africa after the War. Second Edition.*

By C. W. Hobley. With an Introduction by Sir James G. Frazer. H. F. and G. Witherby Ltd., London. 15s. net. 8½ x 5½; 368 + [1]; 1938.

Since the first edition of this work appeared sixteen years ago, many changes have taken place in Africa, partly consequent upon new outlooks and policies inaugurated as a result of the World War. Most of the tribes have in recent years shown a remarkable adaptability and faculty for a degree of self government based on the British system. However, many problems still present a barrier to satisfactory adjustment between the old native social structure and increased European dominance. Hobley has attempted to analyze the principal religious, educational, economic, and governmental problems, and suggests means whereby stresses might be alleviated.

One who wishes to understand the difficulties involved should first have an in-

sight into the ancient native customs. The detailed and often tiresome enumeration of religious beliefs, magic, and laws should prove sufficient for the purpose.

PATAGONIAN YEAR.

By Pedro Rubio. Translated from the Norwegian by Arthur G. Chater. Methuen and Co., London. 7s. 6d. net. $7\frac{1}{4}$ x $4\frac{3}{4}$; v + [2] + 208; 1938.

The author, a Norwegian land surveyor who for some time worked at his profession in Patagonia, narrates a few of the adventures he encountered while on a job there in 1916. As is well known, the country is bleak and uninviting but the author has perceived in the grasslands, dried salt lakes, and sandy deserts a certain beauty and charm which he succeeds in transmitting. The reader is apt at the end to feel a yearning to visit the place. All in all the book makes for interesting and amusing reading because at heart the author is a naturalist and human biologist. There are delightful pen portraits of the hearty Scots, the suave Argentineans and the shy natives with whom the author came in contact, and keen descriptions of the behavior of the animals, from horses to ostriches. It deserves to be read if only to learn something about a country which to many is just a geographic name.

LIFE AND LETTERS OF FIELDING H. GARRISON.

By Solomon R. Kagan. With an Introduction by James J. Walsh. Medico-Historical Press, Boston. $3.00. $8\frac{3}{4}$ x $5\frac{1}{2}$; xvi + 287; 1938.

An incredibly bad attempt at a biography of a great man. Garrison was a profound scholar, who also wrote with clarity, dignity, and charm. The heavy-footed bumbling and bungling of Kagan's *opus* seems somehow an offense to the fine and delicate spirit of its subject, who was as much an artist as a scientist. But quite apart from its literary shortcomings, the book gives no adequate picture of a full and rich life—a life that beautifully exemplified the fact that one may but rarely leave the serene quiet of the study and still not miss much of anything of real importance that the world has to offer.

OUR DAILY BREAD. *A Geography of Production.*

By Sir Daniel Hall. John Murray, London. 6s. net. $7\frac{3}{4}$ x 5; x + 169; 1938.

This simply written little book should fill a gap in the knowledge of many city dwellers, whether adults or children. Starting with breakfast and continuing through dinner and tea the author pounces one by one on the various edibles on the table and describes their origin and mode of production. The loaf of bread at breakfast leads to a discussion of wheat, its geographical distribution, harvesting tools, and the grinding of the grains into flour. In a similar manner the author takes up each dish as it comes along through the noon-day roast to the spices in the afternoon tea cakes. Maps and some excellent photographs illustrate the text. There is an index but no bibliography.

FOOD PLANNING FOR FOUR HUNDRED MILLIONS.

By Radhakamal Mukerjee. The Macmillan Co., New York and London. $2.75. $8\frac{1}{2}$ x $5\frac{1}{2}$; xviii + 267; 1938.

This authoritative review of the Indian economic situation, presents a survey of the trend of the food position in relation to population increase in India and an estimation of her total population capacity and food shortage, following the methods adopted in this connection by Pearl and Taylor for the United States.

The author, head of the Department of Economics and Sociology, Lucknow University, examines the relation between agriculture, nutrition and population in India and establishes certain food standards for the different regions. He pleads for a diminution of India's hordes of superfluous cattle, and discusses remedies of population pressure and the social

attitudes of the country toward marriage and family limitation.

Numerous tables, diagrams and a long and complete index supplement the text.

RAPPORT SUR LE PÈLERINAGE DU HEDJAZ *de l'Année de l'Hégire 1356 (A.D. 1938).*

Conseil Sanitaire Maritime et Quarantenaire d'Egypte, Alexandrie. Free. 12½ x 9¼; 123 + 5 tables; 1938 (paper).

This report embodies essentially the same features that were present in the preceding one (Q.R.B., Vol. 13, No. 2). From all accounts, it is evident that the sanitary precautions imposed upon the members of the pilgrimage have brought very satisfactory results in terms of general health both for the travellers and for the general populations of the lands traversed.

These reports are strongly indicative of the advances in public health and sanitation that can be accomplished when a little bit of honest effort and common sense on the part of the medical director is used.

NATURAL INCREASE AND MIGRATION: *Greater Cleveland 1919–1937.*

By Howard W. Green. Cleveland Health Council, 1001 Huron Road, Cleveland, Ohio. $1.00. 11 x 8¼; 75; 1938 (paper).

The student of population and of migration will find this an exceedingly useful report. The results, presented in tabular and graphic form (10 maps, 26 charts, 16 tables) show the changes in composition and characteristics of the census tracts in Cuyahoga County, during a period of 19 years. Twenty-six brief paragraphs summarize the results—the net result of the study being that births exceed deaths by smaller and smaller margins, the rate of natural increase having "decreased from 17 in 1921 to around 3 during the period 1933 to 1937."

RASSENKUNDE UND RASSENGESCHICHTE DER MENSCHHEIT. *Zweite umgearbeitete und erweiterte Auflage in zwei Bänden. Erster Band. Die Forschung am Menschen. Vierte Lieferung (Bogen 23–31).*

By Egon Freiherr von Eickstedt. Ferdinand Enke Verlag, Stuttgart. RM. 10.80. 10¾ x 7; 353–496; 1938 (paper).

An idea of the extent of the additions made in this second edition (which will comprise two volumes instead of the original one) may be noted from the fact that page 361 of the present *Lieferung* 4 starts the section, dealing with the human form in general, contained in *Lieferung* 1 (beginning page 39) of the first edition noticed in these columns, Volume 8, Number 1. Many new illustrations have been added.

PROCEEDINGS OF CONFERENCE ON BETTER CARE FOR MOTHERS AND BABIES. *Held in Washington, D. C., January 17–18, 1938. U. S. Department of Labor, Children's Bureau. Bureau Publication No. 246.*

Government Printing Office, Washington. 20 cents. 9 x 6; ix + 171; 1938 (paper).

PROCEEDINGS OF THE CONFERENCE ON STATE CHILD-WELFARE SERVICES. *Social Security Act, August 14, 1935, Title V, Part 3. Washington, D. C. April 4–6, 1938. U. S. Department of Labor, Children's Bureau. Maternal and Child-Welfare Bulletin No. 3.*

Government Printing Office, Washington. 20 cents. 9¼ x 5¾; v + 155; 1938 (paper).

PATERNITY LAWS. *Analysis and Tabular Summary of the State Laws Relating to Paternity and Support of Children Born out of Wedlock. In Effect January 1, 1938. U. S. Department of Labor, Children's Bureau, Chart No. 16.*

Government Printing Office, Washington. 20 cents. 10¼ x 7¾; 83; 1938 (paper).

ZOÖLOGY

IN SEARCH OF THE GYR-FALCON. *An Account of a Trip to North-West Iceland. With a Memoir of the Author.*

By Ernest Lewis. Constable and Co., London. 12s. 6d. 8⅝ x 5⅜; xxiii + 234 + [1] + 1 folding map; 1938.

The intrepid adventures of Ernest Lewis will command wide attention and admiration. From a very young boy, along with his keen interest in the birds of his English countryside, he was fired with a lasting ambition to see the gyr-falcon "the grandest of all winged things" in its native eyrie. This he accomplished with probably far greater success than he had dared to anticipate. In view of the untimely death of Mr. Lewis, at only twenty-nine, it is to be fervently hoped that he enjoyed to the fullest the satisfaction of having succeeded in his high venture.

Lewis spent two summer months of 1936 in north-west Iceland on this search. The crossing of the many fjords; the climbing "on the faces of sheer gorges" along narrow, rocky and snowy crags looking for the gyr-falcons' nests offered almost overwhelming difficulties. For him to surmount these hazards required particular ingenuity and courage, as he had suffered the loss of the his left arm and his right eye! But it can be truly said that he took each challenging experience in his stride—belittling every hardship. He went valiantly on and was rewarded by seeing these "matchless birds" in flight and in their eyries with the falcons brooding on the eggs guarded by the stalwart tiercels. Finally Lewis accomplished the almost impossible in taking six of the eyesses back to England in "feather perfect" condition! At the close of the book three of these young birds were still alive and being trained and flown by an expert in the ancient and romantic art of falconry.

The whole book is written most pleasingly in the fine, lucid, straightforward English prose for which the author had so great a talent and which is so conspicuous in his other books. The scientific value of the work is enhanced by photographs, descriptions of many varieties of birds seen, and also by a map of the territory covered in north-west Iceland. The memoir of the author, written by his father, is an illuminating and poignant chapter. It gives the reader further and more intimate insight into the character, rare courage, gallant spirit and unusual gifts of this versatile young naturalist whose writings, in several fields, deserve unstinted praise.

TEXTBOOK OF ZOOLOGY.
By George Edwin Potter. C. V. Mosby Company, St. Louis. $5.00. 8½ x 5½; 915; 1938.

TEXT-BOOK OF ZOOLOGY.
By W. F. Wheeler. William Heinemann Ltd., London. 10s. 6d. 8¾ x 5½; xi + 256; 1938.

TEXTBOOK OF GENERAL ZOOLOGY. *Third Edition.*
By Winterton C. Curtis and Mary J. Guthrie. Wiley and Sons, New York and London. $3.75. 9 x 5¾; xvii + 682; 1938.

The classical collegiate excuse of eyestrain in explaining the lack of a thorough acquaintance with textbooks of zoology has lost its last leg, for Potter has given us an excellent text all done up on a new "eye-toned" paper. But the quality of the paper and the type of print are only two of the text's many admirable features. The author has hit upon something essentially new in pedagogy; a fact which is attested by the careful interweaving of the theoretical and practical phases of biology. The fundamental elements of zoology are presented in the usual manner of a detailed discussion of one or more organisms typical for a particular phylum. In addition to the sections on the classical phases of zoology, there are numerous chapters on such interesting subjects as animal behavior, distribution of animals, conservation, parasitism, genetics, and eugenics. The text is amply supplied with illustrative material, both graphic and photographic. A list of excellent references, a glossary, and a table of contents conclude the volume.

Little difference exists between the second of these texts and numerous other zoology books on the market yet certain features may cause it to be preferred by some educators. Physiological processes are woven into the discussion in connection with those forms best suited to a demonstration of the process at hand. Special chapters, however, deal more generally with the functions of the various organ

systems and in conjunction with them the fundamentals of biochemistry are presented. The final pages are devoted to histological methods for practical studies.

The last volume, a substantial text first appearing 12 years ago (cf. Q.R.B., Vol. 3, p. 140 and Vol. 9, p. 111) follows the same general lines as the two preceding editions, with such alterations, eliminations or additions as the authors deemed necessary.

La Vie des Mouches et des Moustiques. *By E. Séguy. Librairie Delagrave, Paris.* 16 francs (paper); 20 francs (cloth). 7⅜ x 4⅝; 254; 1938 (paper).

Mosquitoes of the Ethiopian Region. *II.—Anophelini. Adults and Early Stages. By Alwen M. Evans. British Museum (Natural History), London.* 20s. 10 x 7; x + 404; 1938.

As complete a résumé as could be given for such a large order as the Diptera is found in the first of these volumes. Séguy presents the material in two sections: the first on flies, and the second on mosquitoes. Each section describes the various egg-laying activities of the females and the life histories of the larvae and adults of the most representative species of the order. The different forms of myiasis caused by the flesh, bot, and warble flies, the rôle of *Glossina* in trypanosome infections, and of course, the part played by mosquitoes as malaria and yellow fever vectors, are all recounted. Apparently the author still believes that warble flies (*Hypoderma*) that attack cattle are taken into the mouth when the animal licks itself. Actually the larvae penetrate the skin at the site where the eggs are laid (chiefly on the hind legs) and migrate to the region of the animal's gullet. However, the general reader will find this book pleasant and instructive reading. There are several illustrations.

The work on the Anophelini of Ethiopia completed after the author's death in 1937, gives an account of the species for that region so far as they are known. Keys to all the stages of their life history are included for ready identification of this important tribe of malaria vectors. This monograph is one in every sense of the word; every species is minutely described in all stages, and whatever is known of their habits, distribution, and relation to malaria is included. Practically every page has an illustration.

The California Woodpecker and I. *A Study in Comparative Zoology in which are set forth numerous facts and reflections by one of us about both of us. By William E. Ritter. University of California Press, Berkeley.* $3.50. 9¼ x 6; xiii + 340.

Dr. Ritter's addicts have come to expect much of him, and this book will not disappoint them. But it will surprise them. The woodpeckers are highly specialized birds, and their Pacific Coast representative is a highly specialized woodpecker. It has abandoned the insectivorous habits of its eastern relatives and subsists almost entirely on nuts which it stores away against the lean days of winter, for it has ceased to be migratory. Its favorite storage place is the bark of oak and pine trees. Dr. Ritter calculated that one tree which he observed had been drilled over 30,000 times by these birds, and estimated that another had nearly twice as many holes in its bark.

The woodpecker's social system is exclusively communistic—about a half dozen birds will cooperate in excavating a community nest, to which all the females will contribute indiscriminately after promiscuous mating. All the birds will then share the incubation, working in shifts, and when the eggs have hatched all the parents will feed all the young.

The subtitle of this book (which does not appear on the cover) shows that it is much more than a mere description of the social, economic, and biological activities of these birds. Dr. Ritter's reflections on what men and woodpeckers have in common and in what respects they differ gives his book great philosophical significance, and renders it thought-provoking. The book is adequately indexed and documented, attractively printed and substantially bound.

ANIMALS WITHOUT BACKBONES. *An Introduction to the Invertebrates.*

By Ralph Buchsbaum. University of Chicago Press, Chicago. $3.75. 9 x 6¾; ix + 371 + 128 plates; 1938.

This is certainly one of the most fascinating treatments of invertebrate zoology that has appeared on the market. The author prefaces the book with the remark that

> Elementary and general accounts of the invertebrates, suitable for the beginning college student or layman, have been limited to two sorts of books: natural histories, which describe the habits of a great many animals but are lacking in descriptions of basic structure and in theory, and formal textbooks, which are packed with morphological detail and technical terminology. This book is an attempt to present the main groups of invertebrate animals in simple non-technical language. Each group is used to illustrate some principle of biology or some level in the evolution of animals from simple to complex forms.

College students are certainly fortunate these days when they may study from textbooks that read like novels. But aside from the text, it is the illustrations that catch this reviewer's fancy. The bold semi-diagrammatic pen-and-ink drawings are executed in such a manner that even the most complex morphological details of construction are extremely lucid. The photographs are also excellent.

CONTRIBUTIONS TO SPECIAL SCIENTIFIC MEETINGS, 1938. *Part I. Rate of Growth. Conseil Permanent International pour l'Exploration de la Mer. Rapports et Procès-Verbaux des Réunions, Volume 108.*

Conseil Permanent International pour l'Exploration de la Mer. Andr. Fred. Høst et Fils, Copenhagen. Kr. 5.00. 10⅜ x 8¼; xv + 114; 1938 (paper).

REPORT OF SPECIAL SCIENTIFIC MEETINGS, 1938. *Part II. Light Measurements. Part III. Salmon Migrations. Conseil Permanent International pour l'Exploration de la Mer. Rapports et Procès-Verbaux des Réunions, Volume 108.*

Ibid. Part II, Kr. 1.00; Part III, Kr. 1.50. 10⅜ x 8¼; Part II, 21; Part III, 35; 1938 (paper). Price for the three parts, Kr. 7.50.

Part I contains sixteen papers on the growth of fish, mostly from the Baltic and North Seas. The contributors include Johan Hjort, Per Ottestad (2 papers), Einar Lea, Oscar Sund, Gunnar Rollefsen (2 papers), L. Fage and A. Veillet, Erik M. Poulsen (2 papers), Michael Graham, K. A. Andersson (2 papers), A. Bückmann, Arvid R. Molander, and Aage J. C. Jensen (2 papers).

Part II includes four papers: The effect of surface conditions on the intensity and angular distribution of submarine daylight, by H. H. Poole; Measurements on the angular distribution of submarine light, by Hans Pettersson; Trial methods of measuring transparency of sea water, by Michael Graham; and a paper in German on carbonic acid assimilation and quality of light in marine plankton diatoms, by E. K. Gabrielsen and E. Steemann Nielsen.

The two papers comprising Part III are: A review of recent salmon marking experiments in Norway, by Knut Dahl; and Some preliminary observations on the migrations of salmon (*Salmon salar*) on the coasts of Scotland, by W. J. M. Menzies.

FAUNA OF THE CAVES OF YUCATAN. *Carnegie Institution of Washington Publication No. 491.*

By A. S. Pearse, with the Collaboration of Nathan Banks, Joseph C. Bequaert, Joseph C. Chamberlin, Ralph V. Chamberlin, B. G. Chitwood, William J. Clench; Edwin P. Creaser, Norma C. Furtos, Helen T. Gaige, Theodore H. Hubbell, Carl L. Hubbs, Libbie H. Hyman, Wilton Ivie, Remington Kellogg, Harlow B. Mills, J. Percy Moore, C. F. W. Muesebeck et al., Grace F. Pickford, Horace W. Stunkard, George W. Wharton, William Morton Wheeler, Charles Branch Wilson, and Frederick A. Wolf. Carnegie Institution of Washington, D. C. $3.00 (paper); $3.50 (cloth). 11½ x 9; iii + 304 + 8 plates; 1938.

During the summer of 1936 the senior writer visited 27 caves distributed throughout the State of Yucatan. The faunal collections were subsequently sent to various authorities for identification and their findings are included in this

report on the cave-dwelling animals of that peninsula. The list includes flatworms, annelids, arthropods, and vertebrates (also the fungal flora). Many species are new to science, indicating that this type of ecological niche deserves further investigation not only to help clear up phylogenetic obscurities of taxonomic interest, but also to help understand the evolutionary processes by which these animals became adapted to their troglodytic life. The writer has included an introduction on the subject of caves and their fauna with especial reference to those of Yucatan.

PROBLEMS OF ANIMAL ECOLOGY.

By F. S. Bodenheimer. Oxford University Press, London. 12s. 6d. 8⅝ x 5⅜; vi + [2] + 183; 1938.

Every science apparently undergoes similar stages of development. The science of ecology as a separate discipline is no exception for as research in that field is being further pursued it becomes evident that "things aren't as simple as they seem." Original interpretations of fundamental "laws" have to be revised, different experimental techniques and approaches have to be devised and with the new data acquired only gradually are the real truths revealed.

The author of this volume points out that problems in animal ecology have to be attacked not only from a qualitative viewpoint, but also from a quantitative or statistical angle. Most biologists, as the author states, are mathematicophobic, and it will undoubtedly take a long time before mathematical analysis will assume its proper place in biology, but its need in the field of ecology is expressed by the author. Habitat concepts, populations, biological equilibria, and the interaction of environment and heredity within the organism are some of the problems discussed.

ZOOLOGICA. *Scientific Contributions of the New York Zoological Society. Volume XXIII, Part 3, Numbers 10–16.*

New York Zoological Society. Zoological Park, New York. $1.50. 10½ x 7; 219–318 + 16 plates; 1938 (paper).

This part contains the following papers: Morphology of the hypophysis of the common goldfish (*Carassius auratus* L.), by W. Randall Bell; Pathology of *Dirofilaria infestation*, by Joel Hartley; Papilloma of the skin occurring in an electric eel, *Electrophorus electricus* (Linnaeus), by C. W. Coates; Arithmetical definition of the species, subspecies and race concept, with a proposal for a modified nomenclature, by Isaac Ginsburg; Eastern Pacific expeditions of the New York Zoological Society. *XIV.* Introduction, itinerary, list of stations, nets and dredges of the Eastern Pacific *Zaca* Expedition, 1937–1938, by William Beebe. *XV.* Seven new marine fishes from Lower California, by William Beebe and John Tee-Van; and Deep-sea fishes of the Bermuda oceanographic expeditions. Family Anguillidae, by A. Vedel Taning.

LIFE HISTORIES OF NORTH AMERICAN BIRDS OF PREY. (*Part 2*). *Orders Falconiformes and Strigiformes. Smithsonian Institution, United States National Museum, Bulletin 170.*

By Arthur C. Bent. Government Printing Office, Washington. 60 cents. 9½ x 5⅝; viii + 482 + 92 plates; 1938 (paper).

This volume is Part 2 of the complete work on the life histories of the North American birds of prey (Part 1 reviewed in Vol. 13, No. 1) and deals exclusively with the orders Falconiformes and Strigiformes. As in the earlier work, Bent has discussed the different species under the headings of (1) habits, which include nesting, number and color of eggs, plumage changes, food and general behavior; and (2) distribution, which incorporates general, breeding and winter ranges, and migration habits. Some 20 species of Falconiformes and some 55 species of Strigiformes have been classified according to the nomenclature of the 1931 Check-List of the A. O. U. The volume contains 92 well chosen photographs of nesting sites, nests, eggs, young, and changes in plumage of a number of species, a bibliographic list of some 520 titles and an index.

AN INVESTIGATION OF THE EFFECTS OF MILK WASTES ON THE BRISTOL AVON. *Fishery Investigations, Series I, Volume 4, Number 1. By F. K. T. Pentelow, R. W. Butcher and J. Grindley. H. M. Stationery Office, London.* 4s. 6d. (Obtainable in North America from British Library of Information, New York). $1.35. 10¾ x 7; 80 + 3 plates; 1938 (paper).

A detailed study on the effect of polution from a milk factory and the recovery of the river afterwards. The most obvious effect was the large growth of sewage fungus. Algae growth also showed a condition of serious polution. Just below the milk factory the river was practically barren of fauna but where the mixing of the effluent with the river water was complete leeches, molluscs and tubificids were found. Many charts, tables and figures exhibit the findings. In an appendix will be found an account of "Methods of chemical examination used in the survey," and plant and fauna lists.

FIELD BOOK OF FRESH-WATER FISHES OF NORTH AMERICA NORTH OF MEXICO. *By Ray Schrenkeisen. Edited by J. T. Nichols and F. R. LaMonte. G. P. Putnam's Sons, New York.* $3.50. 6¾ x 4; xii + 312; 1938.

Here is an excellent comprehensive guide which fulfills a long-felt need. Its author, late associate editor of *Field and Stream*, was well equipped to bring together all the necessary material from widely-scattered sources—monographs, articles in journals and magazines, textbooks, etc. The final work on the manuscript has been ably done by the associate editors. The line drawings throughout the text help to clarify the descriptions and a glossary and extensive index complete what we (although not being fishermen) venture to believe will long be a classic.

MEDICAL ENTOMOLOGY. *A Survey of Insects and Allied Forms which Affect the Health of Man and Animals. Second Edition. By William A. Riley and Oskar A. Johannsen. McGraw-Hill Book Company, New York and London.* $4.50. 9 x 6; xiii + 483; 1938.

Minor changes and additions have been made throughout this text due to developing knowledge concerning such topics as the black widow spider, the value of maggots in the treatment of osteomyelitis and similar infections, the theory of the transmission of kala-agar by Phlebotomus, that equine encephalomyelitis is mosquito-borne, changing viewpoints regarding the distribution and the vectors of Rocky Mountain spotted fever, endemic typhus, Chagas' disease, etc.

DIE WILDLEBENDEN SÄUGETIERE MITTELEUROPAS. *By Wilhelm Bieger and A. Wahlström. Carl Winter's Universitätsbuchhandlung, Heidelberg.* RM. 5. 6⅛ x 4⅜; ix + [1] + 88; 1938).

This little pocket guide to the wild mammals of Central Europe contains first of all a discussion of wild animals in general, their various manners of life, development of senses, reproduction, distribution, duration of life, numbers, etc. Following this general part there are presented descriptions (with illustrations) of the tracks of the several animals, a glossary of German huntsmen's terms, descriptive text and illustrations for each of the animals. Indices of German and scientific names of the mammals are appended.

ANIMAL LIFE IN FRESH WATER. *A Guide to British Fresh-Water Invertebrates. By Helen Mellanby. Foreword by L. E. S. Eastham. Methuen and Co., London.* 8s. 6d. net. 7⅜ x 4⅞; viii + 296; 1938.

This is a guide to use either as a text for schools, where fresh-water life in captivity provides one of the easiest forms of nature study, for the university graduate who has had little contact with field work, and for the amateur naturalist. The pleasing style of the text (one quite forgets that this is a *guide*), the excellent line drawings and the useful index fulfill the purpose of the author.

THE INSECTS OF NORTH CAROLINA.
By C. S. Brimley. North Carolina Department of Agriculture, Division of Entomology, Raleigh, N. C. $2.00. 9 x 6; 560; 1938.

While state check-lists of birds, mammals, and reptiles are fairly abundant, only rarely does one appear devoted to insects. Naturally such an annotation cannot be considered complete, but more than 10,000 species of insects and near insects are listed as having been found or reported from the state. Perhaps this fine list will provide an impetus for similar work in other states.

FIELD GUIDE TO NEW ENGLAND TURTLES. *New England Museum of Natural History. Natural History Guides, No. 2.*
By Harold L. Babcock. New England Museum of Natural History, 234 Berkeley St., Boston, Mass. $1.00. 7¾ x 5; 56; 1938 (paper).

This little booklet is admirably made up and will serve as a valuable adjunct to the nature lover's library of field guides. Each of the eighteen species of turtles listed from New England is described together with something of its life history. Each turtle is also beautifully pictured in color.

AN INTRODUCTION TO THE VERTEBRATES. *Second Edition.*
By Leverett A. Adams. John Wiley and Sons, New York. $3.50. 9 x 5⅝; vii + 479; 1938.

The section on comparative anatomy has been practically rewritten and is now placed following the first section thus transposing the original second section (dealing with mammals as groups) to the back of the book, where it can be studied or not, as desired.

ECOLOGICAL DISTRIBUTION OF THE MAMMALS IN THE CRANBROOK AREA. *Cranbrook Institute of Science, Bulletin No. 13, August, 1938.*
By Harold J. Leraas. Cranbrook Institute of Science, Bloomfield Hills, Michigan. 15 cents. 9 x 6; 20 + 2 plates; 1938 (paper).

Because the plants of an area have a direct influence upon its mammal population, a survey of the distribution of the mammal fauna for a small area in Oakland County, Michigan, is given in this brief bulletin.

THE UNIVERSITY OF COLORADO STUDIES, *Volume 25, Number 4, 1938.* Containing the Following Articles: *A Criterion for Admission to Collegiate Work*, by George H. Light; *Notes on Colorado Operculate Discomycetes*, by Paul F. Shope; *Catalogue of Greek and Roman Coins at the University of Colorado*, by William and Mary Wallace; *Type Specimens of Fossils in the University of Colorado Museum*, by Hugo G. Rodeck.
University of Colorado, Boulder. $1.00. 10 x 6¾; 86; 1938 (paper)

BOTANY

THE WORLD WAS MY GARDEN. *Travels of a Plant Explorer.*
By David Fairchild assisted by Elizabeth and Alfred Kay. Charles Scribner's Sons, New York and London. $3.75. 9½ x 6¾; xiv + 494 + 128 plates; 1938.

Here is a highly significant biography, as well as an illuminating record of a botanist who is a world traveller and a pioneer in agricultural exploration. David Fairchild came from the finest of intellectual stock, and his earliest years were spent in the forest clearing which was the campus of the Michigan State College of Agriculture, the first institution of its kind in the United States. Later he attended the University of Kansas, where his father was called to the presidency in 1879.

To enumerate the men who influenced Fairchild in his choice of a profession, would be to give a roster of this country's early botanists, and the pioneers in the study of the diseases of plants. Fairchild's classmates carried their learning, and their enthusiasm over agricultural problems, into all the corners of the globe

and he frequently visited them in his years of extensive travel in search of plants and foods for introduction into the United States. The account of these friendships with many scientists, and the recollections of their individual contributions to the botanic and economic development of the United States during the last sixty years, weaves a brilliant and delightful pattern of reminiscence all through the book.

The number of plants, fruits, and vegetables introduced from Europe, Asia and Africa by Fairchild and his co-workers, and successfully established under suitable climatic conditions in different parts of this country, is truly astonishing. They are so varied that they seem to include almost all of the items on a present day American menu for either man or beast!

All readers and students of this profoundly worth-while and delightful book will feel a lasting gratitude to Elizabeth and Alfred Kay for having finally succeeded in persuading Fairchild to write of his life's work, and his unique opportunities in exploring the gardens of the world. The two hundred photographs used in illustrating the book were taken by the author, and form a remarkably vivid record of his travels. The nine-page index is indicative of the careful preparation of the text.

THE AMERICAN PLANT MIGRATION. *Part I. The Potato. Anthropological Series, Field Museum of Natural History, Volume 28, Number 1, July 28, 1938. Publication 418.*

By Berthold Laufer. Prepared for Publication by C. Martin Wilbur. Field Museum of Natural History, Chicago. $1.50. 9½ x 6; 132; 1938 (paper).

This treatise on the potato, by the late Berthold Laufer of the Field Museum, is far more entertaining than anyone would expect from only the daily acquaintance from childhood that one has with this article of food. All of the varieties of the potato—and there are now about a thousand of them not including the sweet potato which is quite another plant—derive from one single species, *Solanum tuberosum*. It is known that the home of this species is in the Andes of South and Central America although it has never yet been found in the wild state. The great adaptability of the potato to climate, elevation and soil has made what was once a despised article of food, when introduced into older civilizations, now an article of staple diet. That it is a plant of great antiquity is known by the dried remains found in Inca graves and by ancient Peruvian vessels and whistles made in the shape of the potato. From the seed there is chance of procuring a new variety but the eyes of the tuber seldom produce other than the kind planted. The author traces the migration of the potato (together with its changing characteristics) into all countries of the world, and the progress of its rise to an important place in the diet of many peoples. He includes an appendix on nomenclature and on world statistics of the potato, a bibliography, and an index.

ALICE IN VIRUSLAND.

By Paul F. Clark. Society of American Bacteriologists, University of Wisconsin, Madison, Wis. $1.00. 10 x 7; 23; 1938.

A trip down almost any "rabbit hole" is exciting, but bacteriology's Alice has the doubly interesting experience of being given a "germ's eye" view of human beings, and of hearing a chat between Theobald Smith and Antony van Leeuwenhoek. Overhearing this conversation is just one of the things that happens to Alice in that strange land at the bottom of the ventilator shaft where Ferdinand the monkey leads her. In not the least of her adventures she must answer charges of man's

> Brutality and blind-spots.
> Power to the panderers and paranoiacs.
> Blind selfishness and blundering sentimentality!

But Alice escapes conviction and is sent by the Microbe Parliament across the river Styx to ". . . consult the shades of some of the humans that have had sense enough to study us. They must surely

be the wisest." Here, as she meets Pavlov, a bell rings, and he invites her to tea. Though she enjoys her bread and butter and jam, she doesn't "quite understand" the ideas Erasmus and the Unknown Soldier exchange, and is glad to chase Ferdinand again.

In such a gay, gentle way, Professor Clark exposes a few weaknesses of the human species, ending his brief paper with an epilogue, taken from Epictetus: "He who remembers what man is, can be discontented at nothing which happens."

No review of this book would be complete without a reference to its amusing rhymes and illustrations. All bacteriologists should read at least the description of a virus, and the Spirochaete Chant, noting meanwhile that the book is the presidential address delivered before the Society of American Bacteriologists at its 40th annual meeting last year.

AN INTRODUCTION TO BOTANY.
By Arthur W. Haupt. McGraw-Hill Book Co., New York and London. $3.00. 9 x 6; xii + 396; 1938.

A TEXTBOOK OF GENERAL BOTANY *for Colleges and Universities. Fourth Edition.*
By Richard M. Holman and Wilfred W. Robbins. John Wiley and Sons, New York; Chapman and Hall, Ltd., London. $4.00. 9 x 5¾; xvii + 664; 1938.

The first book listed is a clear, concise, and comprehensive study of botany including in its scope all the fundamental concepts common to both animal and plant life. The gross aspect of the vegetative organs is described previous to the study of minute structural details, so that the student is given a complete picture of the general functions of the plant body as a whole. The book, intended for use in a general biology course, has many helpful drawings and photographs.

The same plan in the organization and treatment of the subject matter has been adhered to in the revision of the second of these texts that the senior author, the late Professor Holman, had outlined for the earlier editions, but recent researches have required considerable revision and additions, particularly in certain fields such as the absorption and conduction by roots, rise of sap in stems, conduction of foods, hormones and the classification of tissues. A glossary, which includes the origin of words as well as the definition of terms, has been added.

LEAF XANTHOPHYLLS. *Carnegie Institution of Washington Publication No. 490.*
By Harold H. Strain. With a Foreword by H. A. Spoehr. Carnegie Institution of Washington, D. C. $2.00 (paper); $3.00 (cloth). 10 x 6¾; xi + 147; 1938 (paper).

It is possible to list only a few of the findings of this work.

"The xanthophylls from the leaves of a number of different species of plants are mixtures of twelve or more pigments. These xanthophylls are mono-, di-, tri-, and tetra-oxy derivatives of carotenes. The principal constituent of the mixture is lutein." . . . "The only satisfactory method for the separation of all the leaf xanthophylls from one another is chromatographic adsorption." . . . [They] "are so similar that it has not been possible to devise quantitative methods for their separation." . . . "The crystalline leaf xanthophyll isolated by present methods is usually contaminated with colorless substances." . . . "A study of the properties of the pure xanthophylls and of mixtures of these has demonstrated that a pure pigment can be identified as such only by the determination of a number of its physical and chemical properties."

Graphs, tables and figures are given in the text and the work concludes with a bibliography of 190 titles, and an author and a subject index.

SAGAS OF THE EVERGREENS. *The Story and the Economic, Social and Cultural Contribution of the Evergreen Trees and Forests of the World.*
By Frank H. Lamb. W. W. Norton and Company, Inc., New York. $3.50. 8½ x 5½; xi + 364; 1938.

This is in no way a scientific treatise although the author has a wide acquaintance with trees in the technical sense. "The pages are but the absorption of forty years of association with trees and men of the trees, and many thoughts and ideas are what I have gained from them." Mr. Lamb has seen every forest area and

every forest industry in the United States from Alaska to Panama and has visited all of the great forests of the world. His book makes available to tree lovers a wide range of accurate and odd bits of information concerning the history and cultivation and uses of the evergreen, beginning, of course, with the Ginkgo. The volume is abundantly illustrated and contains a selected bibliography and a carefully prepared index.

AN INTRODUCTION TO INDUSTRIAL MYCOLOGY.

By George Smith. Foreword by Harold Raistrick. Edward Arnold and Co., London; Longmans, Green and Co., New York. $5.20. $8\frac{1}{2}$ x $5\frac{1}{2}$; xii + 302; 1938.

This book is intended to assist those who are commencing the study of "moulds" rather than of fungi in general. . . . There has been up to the present no book in English, apart from highly specialized monographs, dealing particularly with the fungi which are of importance in industry.

Sufficient general mycology is included to enable the student to follow up the subject in the standard text-books. The major portion of the book, however, consists of descriptions and illustrations of most of the genera of moulds which are of regular occurrence in industrial products, with more detailed consideration of the genera which are of greatest importance.

The volume contains many excellent illustrations, literature lists complete each section, the final chapter gives a list of mycological journals, standard texts, etc., and there is a useful index.

PHYTOGEOGRAPHICAL PROBLEMS OF EASTERN CANADA. *Contributions du Laboratoire de Botanique de l'Université de Montréal. No. 30.*

By Frère Marie-Victorin. Institut Botanique, Université de Montréal, Montréal. 50 cents. 9 x 6; 70; 1938 (paper).

A study of the flora of eastern Canada gives fresh evidence concerning the great age of some of the forms, as well as the more recent formation of species and varieties. A comparison of their features, and mapping of their ranges show that there are endemic species, that is, species with a limited and consistent distribution. Also it becomes evident that there are epibiotic species, that is, survivors of extinct floras or associations, persisting as relics far away from their main present ranges. The distribution of many plant forms, the effect (on distribution) of the glacial and interglacial periods, soil chemistry, the nuntak theory also are among the topics discussed. Many charts, maps and figures add to the interest of the text.

EXPERIMENTS IN PLANT LIFE.

By William J. Claxton. Wells Gardner, Darton and Co., London. 3s. 6d. net. $7\frac{1}{4}$ x $4\frac{1}{2}$; xiv + 104; 1938.

For the wide-awake boy or girl who is interested in individual experimentation, especially in the field of botanical wonders, this little volume should be a valuable guide. The substance of the book is centered around 30 experiments intended to lead to an elementary knowledge of the soil and of the physiology and economy of a number of our common species of plants.

The book is cleverly illustrated, and is written in such a manner as to be thoroughly understood by a child of early high school age. It may prove itself worth while even to those oldsters of us who were not fortunate enough to be able to dabble in the mysteries of the plant world either in high school or college.

THE STRUCTURE OF ECONOMIC PLANTS.

By Herman E. Hayward. The Macmillan Co., New York. $4.90. $9\frac{3}{8}$ x $6\frac{1}{4}$; x + 674; 1938.

A useful book, especially in the teaching of applied botany. The first part of the volume deals with the point of view of developmental anatomy together with the nomenclature used in Part II. In Part II the author has brought together, from widely scattered sources, material dealing with the structure and developmental anatomy of certain economic plants. Altogether sixteen plants are discussed

in as many chapters and are as follows (we omit the technical names): corn, wheat, onion, hemp, beet, radish, alfalfa, pea, flax, cotton, celery, sweet potato, white potato, tomato, squash, lettuce. The chapters conclude with literature citations. There are 340 text figures, and an adequate index.

PLANT FORM AND FUNCTION.
By F. E. Fritsch and E. J. Salisbury. G. *Bell and Sons, Ltd., London.* 17s. 6d. $8\frac{3}{8}$ x $5\frac{1}{4}$; viii + 668; 1938.

The preparation of this book—a combination of the authors' two previous works, *An Introduction to the Study of Plants* and *An Introduction of the Strutucre and Reproduction of Plants*—has involved many changes and additions in the text material and an increase in the number of illustrations so that it is practically a new work. In scope, it more than covers the first year university syllabus and aims to provide an adequate foundation for a non-specialized graduate course. The volume is abundantly illustrated and well documented and contains an extremely useful index.

PLANT GROWTH-SUBSTANCES, *Their Chemistry and Applications, with Special Reference to Synthetics.*
By Hugh Nicol. Chemical Publishing Co., New York. $2.00. $7\frac{7}{8}$ x 5; xii + 108; 1938.

Two chapters for the layman introduce the subject of this book which is written by the assistant bacteriologist of the experimental station at Rothamsted. The succeeding chapters are necessarily technical but not impossible of mastery by the intelligent reader interested in the chemistry of growth-controlling substances. Information is given which will be of use to gardners, horticulturists, botanists, biochemists and pathologists. The various chapters are well documented and the book contains a number of illustrations and an authors' index.

FERNS OF THE SOUTHEASTERN STATES. *Descriptions of the fern-plants growing naturally in the States south of the Virginia-Kentucky State line and east of the Mississippi River.*
By John K. Small. Drawings by Ruth S. George. Science Press, Lancaster, Pa. $3.50. $8\frac{1}{2}$ x 6; 517; 1938.

This manual has been prepared for the tourist as well as for the student. Of the 196 species listed and figured about 30 have never before been described. It was the belief of the late Dr. Small that "it is probable that fern discoveries of importance can still be made in the southeastern states." In addition to being an excellent guide, well illustrated, with glossary and index, the volume contains an interesting section on the cultivation of ferns.

WILD FLOWERS OF OHIO.
By Harold L. Madison. The Cleveland Museum of Natural History, Cleveland, Ohio. $1.50. $6\frac{3}{4}$ x $3\frac{3}{4}$; 190; 1938.

In this condensed pocket guide all unnecessary material has been eliminated. Opposite each left-hand page, on which are briefly described from eight to thirteen plants, are line drawings (usually excellent although small, *ca.* 1" x $1\frac{3}{8}$") showing the necessary features of the plants listed. We give a sample of the text: "676. Round-leaved Mint. *Mentha rotundifolia.* Lavendar. Spikes 2–4 in. long in fr. Plant hairy, lvs. wrinkled and not veined below. July–Sept. Waste places." A detailed index and glossary are included.

ALGAE: *The Grass of Many Waters.*
By Lewis H. Tiffany. Charles C Thomas, Springfield, Illinois. $3.50. 9 x $5\frac{1}{2}$; xiii + 171; 1938.

The author states in the preface that his book is not written for those who already know about algae. For those who do not, whether amateur naturalist or student, this will be found an entertaining treatise—written largely from an ecological point of view but devoid of formidable technical language, generously

illustrated, and containing a list of references and an index. It provides a reason for the vacationer, who plans to dwell near a body of water, to include a microscope in his equipment.

THE DISTRIBUTION OF IMPORTANT FOREST TREES OF THE UNITED STATES. *United States Department of Agriculture Miscellaneous Publication No. 287.*

By E. N. Munns. Government Printing Office, Washington, D. C. 35 cents. 11⅜ x 9; 175; 1938 (paper).

One hundred and seventy maps show the distribution of as many species and varieties of forest trees. This survey has been many years in the making and is still incomplete. One of the objectives "of the present publication . . . is to stimulate interest in the accumulation of more accurate information on the distribution of our North American trees." A useful source book for the forester and lumberman, the naturalist and botanist, as well as the manufacturer.

COMMON BRITISH GRASSES AND LEGUMES.

By J. O. Thomas and L. J. Davies. Longmans, Green and Co., New York and London. $2.20. 8½ x 5⅝; vii + 124; 1938.

"This book contains a general description of the common grasses and legumes with which the British farmer is concerned. It is intended as a guide to the identification of the various species in the field, and has been written to meet the needs of farmers, schools, young farmers' classes and Agricultural Colleges." The volume is generously illustrated, has a reference list of 22 titles, a glossary and an index.

TREES AND MEN.

By Eleanor Hughes-Gibb. Alexander Moring, London. 8s. 6d. net. 9¾ x 7¼; viii + 170 + [1]; 1938.

Waxing poetic and religious in turn, the author writes lengthily about God and man and trees in general, and more specifically about the products of trees, afforestation in various countries, parasites, forest fires, etc. The volume is illustrated by photographs and some rather nice drawings by Archdeacon Lonsdale Ragg. There is an adequate index but no bibliography.

THE PHYSIOLOGY OF PLANTS.

By William Seifriz. John Wiley and Sons, New York; Chapman and Hall, London. $3.50. 9 x 5¾; vii + 315; 1938.

This volume has been written for the student who has a background in general botany, physics and chemistry. It is well documented, illustrated, and indexed and should be useful to teachers of plant physiology.

BACTERIOLOGY *For Students in General and Household Science. Fourth Edition.*

By Estelle D. Buchanan and Robert E. Buchanan. Macmillan Company, New York. $3.50. 8⅜ x 5½; xv + 548; 1938.

In the revision of this text the keys to families and genera in the chapters on classification of bacteria, yeast and molds have been expanded and placed in the appendices. A chapter on the characters of viruses and bacteriophages has been added.

MORPHOLOGY

CONTRIBUTIONS TO EMBRYOLOGY. *Volume XXVII, Nos. 160 to 169. Carnegie Institution of Washington Publication No. 496.*

Carnegie Institution of Washington, D. C. $4.50 (paper); $5.50 (cloth). 11½ x 9; 305 + 44 plates; 1938.

The following papers appear: On the placentation of the Macaque (*Macaca mulatta*), from the time of implantation until the formation of the definitive placenta, by George B. Wislocki and George L. Streeter (13 plates, 1 text-figure). The investigators divide the early period of placental development in the macaque into three stages (up to the 35th day, when the placenta has eventually attained its final character). These stages, begin-

ning with the 9th day are described and comparisons are made with those of man, of platyrrhine monkeys and of tarsius.

The Yale embryo, by Elizabeth M. Ramsey (3 plates, 1 text-figure). This study of an embryo 13–14 days old lends support to opinions concerning the early development of the human embryo "long current but admittedly based upon too little evidence for acceptance as established facts."

A human embryo in the bilaminar blastodisc stage (the Edwards-Jones-Brewer ovum), by John I. Brewer (9 plates). This embryo, obtained by hysterectomy, was fixed immediately after removal so that there was no post-mortem change or distortion. A very clear picture of the condition of a normal, 15-day-old human embryo.

Young human ovum detected in uterine scraping, by Elemér Scipiades, Jr. (1 plate). The age of this embryo (probably somewhat distorted, due to the scraping and faulty fixation technique) is placed at 11 to 12 days.

Some observations on the vascular system of a female fetal finback, by Robert Walmsley (5 plates, 27 text-figures). A systematic description of the vascular system of a female fetal finback 1430 mm. long. This is supplemented by histological accounts of many of the tissues.

Ovaries of gorilla, chimpanzee, orang-utan and gibbon, by Saïm Săglik (5 plates). The material forming the basis of this paper comprises the ovaries of three gorillas, two chimpanzees, one orang-utan and one gibbon. Comparisons are made with Old and New World monkeys and with human ovaries.

The morphogenesis and histogenesis of the thymus gland in man: In which the origin of the Hassall's corpuscles of the human thymus is discovered, by Edgar H. Norris (7 plates, 1 text-figure).

Multiplication and reduction of somatic chromosome groups as a regular developmental process in the mosquito, *Culex pipiens*, by Charles A. Berger (1 plate, 10 text-figures).

The history of the first somite in human embryos, by Leslie B. Arey (1 plate, 2 text-figures).

Bodily growth of babies during the first postnatal year, by Charles B. Davenport (1 text-figure, 4 tables, 13 graphs). This last study in this series is statistical in nature and summarizes the results on 34 babies, measured repeatedly in 49 dimensions during the first year of postnatal life

All of these papers are accompanied by literature lists. It is hardly necessary to point out that the technique and execution of the illustrations are excellent.

THE EMBRYOLOGY OF THE OPOSSUM. *The American Anatomical Memoirs No. 16.* *By Edward McCrady, Jr. The Wistar Institute of Anatomy and Biology, Philadelphia.* $5.00. 10 x 6⅞; 234; 1938 (paper).

The Virginia opossum (*Didelphis virginiana* Kerr) is an extremely abundant primitive marsupial and is easily caught in almost every part of the United States from about the latitude of Pennsylvania south. It is, however, difficult to domesticate and not until bone meal was added to the diet did the rachitic conditions, developed in domesticated opossums, disappear.

Starting with descriptions of the ovarian egg and testicular sperm the author minutely describes the 35 stages of embryonic development from the time of fertilization to the time of parturition 12¾ days later. The post-natal development in the 80-day period of "pouch-housing" following birth is also described. Various researches on the development of hearing in the newborn opossum and experiments on the opossum embryos near birth are discussed. In all cases the experimental techniques are given.

The evidence obtained by the author seems to support Huxley's theory that the Prototheria split into two branches, one of which became the modern Monotremata, the other giving rise to the Metatheria which in turn split to form the modern Marsupials and the Eutheria. The author does not believe that the marsupials are the result of a degeneration from a eutherian condition.

In addition to 3 plates showing the 35 stages of development, there are many other illustrations which are completely

explained in the text. There is an extensive bibliography.

BIOGRAPHY OF THE UNBORN.

By Margaret Shea Gilbert. Williams & Wilkins Co., Baltimore. $1.75. 8½ x 5½; x + 132; 1938.

The development of the human organism from a helpless single-celled fertilized ovum to a many-celled eight pound bawling baby is a drama full of mystery, fact and fiction. The process of embryological development has always been an absorbing study, but to the layman who is anxious to learn about his intrauterine history the mass of accumulated facts are too recondite and scattered to satisfy his curiosity. The author of this book comes to the rescue by presenting the biography of the embryo from conception till birth in a non-technical, yet substantially accurate, manner. The progressive development of the embryo is taken in nine stages, one for each month of gestation. Fertilization, implantation, placental interchange, and birth, besides the actual process of growth of the various systems of the fetus itself, are intelligibly described. Numerous drawings help to illustrate the text.

Out of sixty-one entries, Mrs. Gilbert's was chosen to receive the award offered by the publishers for the best manuscript on a science subject calculated to interest the general reader.

ÉLÉMENTS D'EMBRYOLOGIE.

By A. Celestino da Costa. Masson et Cie, Paris. 120 francs. 9⅛ x 6½; viii + 494; 1938 (paper).

Originally this work was published in Portuguese in 1933. Being a textbook for medical students, it emphasizes human embryology and contains numerous sections devoted to pathological conditions and anomalies of development. The first part of the book treats of gametogenesis and Mendelian heredity, thus furnishing an excellent biological background to the further sections on embryology in general and the more specific formation of the various organ systems. The appendix is a compendium of historical studies in the subject. A well-illustrated text.

THE NERVOUS SYSTEM. *A Guide for Use with the Educational Sound Picture "The Nervous System."*

By James A. Brill in collaboration with Frederick T. Howard and Ralph W. Gerard. University of Chicago Press, Chicago. 15 cents. 8 x 5⅜; iv + 30; 1938 (paper).

This study guide is issued in connection with an educational sound picture on the nervous system. It deals briefly with: Functions of the nervous system, major divisions of the nervous system, structure of the nerve, structure of the nerve cell, connections of nerve cells with one another, nature of nerve impulses, relation of the nervous system to the whole body, comparative anatomy of the nervous systems of man and other vertebrates, and nature of neural pathways.

INDIVIDUALITÄT UND FORTPFLANZUNG ALS POLARITÄTSERSCHEINUNG. *Die Herabwanderung der Keimdrüsen der Säugetiere im Lichte organismischer Auffassung.*

By Armin Müller. Introduction by J. H. Schultz. Concluding remarks by A. Portman. Verlag von Gustav Fischer, Jena. RM. 3. 9⅝ x 6½; [8] + 66; 1938 (paper).

This is a discussion of various theories on the descent of the mammalian gonads, such as Steiner's law of "migration to the head end," Monokow's view of "migration to the frontal pole," physical dominance and subordination (Cuvier, Child, Mittasch), "specific psychic valence" of organs (v. Weizsäcker), and others. The author himself leans toward the architectonic (structural) view. The book is documented, replete with quotations, and there is an index of authors and subjects.

PHYSIOLOGY AND PATHOLOGY

VITAL ENERGETICS. *A Study in Comparative Basal Metabolism. Carnegie Institution of Washington Publication No. 503.*

By Francis G. Benedict. Carnegie Institution of Washington, D. C. $2.00 (paper); $2.50 (cloth). 10 x 6¾; vii + 215; 1938.

Studies in evolution and genetics have dealt almost entirely with structural form, with some emphasis upon function, but with little, if any, consideration of the most characteristic phenomenon of life, that is, the production of heat. It is our effort to compare with the present-day data available the heat production of animals of various forms, including not only cold-blooded animals but especially warm-blooded animals and likewise those that are heterothermic, the hibernating animals. For the purpose of our discussion we are confining ourselves exclusively to the higher forms of life which are characterized by striking differences in structure or form, differences demanded by the requirements of the organisms to adjust themselves to the different conditions, either of temperature or of the character of vegetation, temperature affecting external conditions such as fur and fatty deposits and the character of the feeds affecting the digestive system.

Only a brief listing of some of the important findings can be given which by no means indicate the scope of the work.

First, in general the larger the animal the larger the total heat production. Secondly, as has been known for decades, the heat production is not constant per unit of weight, and thirdly, it is clearly demonstrated that the heat production is not constant per unit of surface area. . . . From the various comparisons of animals in the same species and in the same weight group, the sex difference *per se* is accentuated as perhaps never before. This is notably the case with men and women and with the bovines, and there is also a hint of a sex difference in the adult pig and goat, although the data are as yet not complete enough to more than suggest this. In each case the difference in metabolism is pronounced and demands an explanation other than any possible slight differences in surface area. . . . *With different species* in the same weight group there are great differences in the total heat production, and in the metabolism expressed per kilogram and per square meter. . . . Another factor to be taken into consideration is the variability of the basal metabolism, shown in a number of animals, notably the ruminants. This variability may be in great part a factor of food. A most striking illustration is the difference in the metabolism of cows that had been grazing and the same cows when fed dry rations. . . . Closely related to the effect of food, which in the last analysis, may be considered perhaps a type of stimulus, are the effects of varying stimuli on metabolism. . . . The suggestions enumerated above apply specifically to the warm-blooded group and by no means exhaust the possibilities for thought. With the poikilotherms the situation is different, for the type of thermic reaction is different, in that there is no zone of thermic neutrality. . . . In these animals [heterothermic], certainly in the marmot, the temperature relations are different from those obtaining with other warm-blooded animals, and the Q_{10} law, which holds so rigidly with the cold-blooded animals, does not obtain, save at higher cell temperatures.

MAN AND HIS BODY.

By Howard W. Haggard. With an Introduction by Yandell Henderson. Harper and Brothers, New York. $4.00. 8½ x 5½; xiii + 594 + 9 plates; 1938.

THE SCIENCE OF HEALTH AND DISEASE. *A Textbook of Physiology and Hygiene. Revised Edition.*

By Howard W. Haggard. Harper and Brothers, New York and London. $3.00. 8½ x 5½; xiii + 594 + 9 plates; 1938.

These books are simple, non-technical presentations of applied physiology. Haggard has done a good job of making understandable material which, to the reader unversed in science, usually seems to be written in the foreign language of biological terminology. Enough anatomy has been included to furnish a clear foundation for the discussion of bodily functions in health and in disease. No doubt the penetrating reader will be aroused to pose further questions for his family doctor to answer, and perhaps the suggestible patient will develop new aches and pains for him to treat.

It is puzzling to note that the "revised edition" of the second book seems to be like the first edition except in the title page and price, and in its designation as a textbook. Those who enjoyed the earlier edition would be pleased to find in *The Science of Health and Disease* more of the same material. So they will, but in a literal sense. This seems to be the same book (*Man and His Body*) over again.

THE WHEEL OF HEALTH.

By G. T. Wrench. C. W. Daniel Co., London. 6s. net. 8⅞ x 5½; 146; 1938.

The three transferences from soil to vegetable, vegetable to animal, animal and vegetable back to the soil, constitute the eternal wheel of health in the eyes of the author. He is a thorough-going nutritionist, considering proper food as the panacea for all ills, human and otherwise.

In a valley walled by mountains three

miles high, where India meets Afghanistan, may be found the State of Hunza. This valley is a sort of "Lost Horizon," for in it dwell people of extreme physical vigor, endurance, and length of life. The author wanted to break away from the pathological or negative study of health and approach it from the opposite end of the scale—the healthiest people he could find—the Hunza. His writing is based on the work of Dr. Robert McCarrison who studied deficiency diseases in India and transferred the human studies to whole-diet experiments on rat populations. On the basis of these experiments Wrench concludes that the causes of pneumonia, middle-ear infection, and peptic ulcers are respectively faulty food, faulty food, and primarily faulty food. Why the concession?

MARIHUANA. *America's New Drug Problem. A Sociologic Question with Its Basic Explanation Dependent on Biologic and Medical Principles.*

By Robert P. Walton. Foreword by E. M. K. Geiling and a chapter by Frank R. Gomila and M. C. Gomila Lambou. J. B. Lippincott Co., Philadelphia. $3.00. 9 x 6; ix + 223 + 13 plates; 1938.

This book is much better than its jacket and title might lead one to suppose. Popular songs, fiction, and newspaper and magazine articles have painted a lurid picture of marihuana. What is fact, what fancy, has been difficult to decide without a study of reports in scattered scientific journals, together with the account of *Cannabis* in textbooks of pharmacology. This monograph makes easily accessible the data from such sources. It offers no solution to "America's new drug problem," but does present a basis for an attack on it.

Opening his study with a history of the hashish vice and a description of the hemp plant, the author proceeds to analyze the chemical and pharmaceutical properties of the drug. In other chapters he summarizes the observations of various workers on its biological effect, which "is probably due to the removal of the usual restraints and correspondingly to the release of the more primitive impulses." The descriptions of hashish experiences make colorful reading.

The section contributed by the New Orleans Public Safety Commissioner is timely. It is interesting to note that "the most serious aspect of the marihuana problem is the extent to which the vice contributes to juvenile delinquency, serves as an introduction to other more-potently addicting drugs, and conditions the petty criminal to perform truly desperate acts of violence."

BIOLOGY AND PATHOLOGY OF THE TOOTH AND ITS SUPPORTING MECHANISM.

By Bernhard Gottlieb and Balint Orban. Translated and edited by Moses Diamond. The Macmillan Co., New York. $5.00. 9¼ x 6; xii + 195; 1938.

Much of what has been looked upon as disease manifestations now looms up as regularly occurring physiologic processes. One cannot minimize the import of a correct evaluation of the normal physiologic mechanism in an understanding of disease. The study of the disease manifestations of the peridontal tissues by Gottlieb and Orban is therefore based upon their reevaluation of the normal. Traumatic occlusion ceases to be a clinical entity subject to whimsical interpretation.

The above is quoted from Dr. Diamond's preface. He considers this work to be so important for routine dental practice that he hopes it will become known to the dental profession generally.

The book includes chapters on the supporting mechanism of the tooth; accelerated tooth eruption; gingival inflammation, Schmutz pyorrhea; parodontal pyorrhea; diffuse atrophy of the alveolar bone; and traumatic occlusion. Attention is particularly called to the authors' concepts "of the gingival crevice, and of the physiologic mechanism of continuous eruption" and "of the continuous deposition of cementum as a physiologic process, and of the tooth as the vital organ to the needs of which the surrounding and supporting tissues are subservient."

Dental anatomists who have heard of the investigations of Gottlieb and Orban will welcome this translation of the contributions which these Viennese workers made prior to their migration to America.

Diamond has made some additions to the text.

GUINEA PIGS AND BUGBEARS.

By G. L. Eskew. Research Press, Chicago. $1.50. 8¾ x 5¾; [10] + 269 + [3]; 1938.

Two hundred and sixty-nine pages of Mr. Eskew's book are devoted to a bitter personal attack on the organizers and officers of institutions for consumer guidance. No rhetorical technique of satire and belittlement is spared in this adverse criticism, whether or not it is justifiable. One of the consumer bulletins ("BULLetins" as Mr. Eskew puts it) issued a statement concerning the harmful effects of tobacco. *Guinea Pigs and Bugbears* answers by associating the increased use of tobacco with the facts that college boys and girls now average two inches taller and seven pounds heavier than they did forty years ago, and life expectancy of the average American is now 61 years as compared to 38 a century ago.

It is regrettable that abundantly deserved criticism of much of the "consumer research" material going to the public is not more temperately stated.

HIBERNATION AND MARMOT PHYSIOLOGY. *Carnegie Institution of Washington Publication No. 497.*

By Francis G. Benedict and Robert C. Lee. Carnegie Institution of Washington, D. C. $2.00 (paper); $2.50 (cloth). 10 x 6¾; x + 239; 1938.

A painstaking survey of the physiological processes of the ground-hog is embodied in this volume. Although natural hibernation was not simulated as closely as one could wish, the task was difficult because of the conditions necessary for careful measurement of weight, temperature, heart rate, respiration, vaporization, and nitrogen secretion. As is often the case, the very absence of normal conditions brought to light several interesting features, one of these being that marmot hibernation is not due merely to seasonal effect, but by artificial influence may be induced at any time of year. The normal physiology of the non-hibernating animal is greatly altered during the hibernating period. Depending on environment the body temperature during hibernation may go as low as 3°C., the respiration rate may descend to 1 in 5 minutes, and the heart rate to 4 per minute. The waking process causes an explosive increase in physiological activity far above that of the normal non-hibernating marmot. Causes and theories of hibernation are discussed in the final pages, and comparisons are made among different animal forms.

FORSCHUNG ÜBER DIE TUBERKULOSE DES LANDWIRTSCHAFTLICHEN BEZIRKES. *Rassenbiologische Untersuchungen des hygienischen Instituts an der medizinischen Fakultät zu Kanazawa. Number 6. Under the direction of Prof. Dr. Y. Koya.*

Edited by Y. Koya. Hygienisches Institut an der medizinischen Fakultät, Kanazawa, Japan. 10⅛ x 7¼; 239; 1938 (paper). [In Japanese.] [Separate in German: "Beitrag zur Erforschung der Tuberkulose unter der Landbevölkerung in Japan," by Y. Koya. Pp. 10.]

Among the findings of this study on tuberculosis in the rural areas of Japan is that the mortality rates from this disease were higher in rural areas near the cities than in the cities themselves, but that they decreased with distance from urban centers, and were very low indeed in the mountain regions. The author explains these differences in the following way: in the cities, although the infecting agents are more prevalent, preventive measures of various kinds are also more common; in rural areas the causal organism is not of such frequent occurrence but the population is not well equipped to defend itself against it (some rural inhabitants also go to town to work in the factories and contract the disease there); in areas distant from cities and in the highlands the tubercle bacillus is rarely present.

Those interested in tuberculosis epidemiology would doubtless find much of interest in this book were it written in a language more widely known than Japan-

ese. The German supplement contains only a part of the investigation and results.

EFFECT OF CHRONIC VITAMIN E DEFICIENCY ON THE NERVOUS SYSTEM AND THE SKELETAL MUSCULATURE IN ADULT RATS. *A Neurotropic Factor in Wheat Germ Oil.*

By Lárus Einarson and Axel Ringsted. Levin and Munksgaard, Copenhagen; Oxford University Press, London. Kr. 12.50. 9½ x 6½; 163; 1938 (paper).

"In this work 'vitamin E-free diet' always means a food mixture very poor in vitamin E but dependent upon the greater or smaller amount of vitamin E contained in the integrant components of the diet and the destruction of this vitamin in being mixed and stored with the oxidised lard."

In a survey of the results of their work the authors point out that (a) the gross picture of the muscular changes points decidedly to a muscular atrophy of spinal origin—a neurogenous muscular atrophy —but that they have been unable to exclude the possibility that the muscular changes may in part be dystrophic and partly be due to the spinal changes, (b) that the vitamin E deficiency might influence not only the cerebrospinal nervous system but also the sympathetic nervous system and that "it is conceivable that the testicular degeneration thus eventually may have to be considered as a neurogenous phenomenon." Numerous figures exhibit the cytological effects of the experiments, and the study concludes with a bibliography of about 70 titles.

DIE PHYSIOLOGIE DER FISCHATMUNG.

By Michael Leiner. Akademische Verlagsgesellschaft, Leipzig. 12 gold marks. 10 x 6½; 134; 1938 (paper).

This interesting and profusely illustrated book is a thorough study of the breathing mechanisms of fish. The first chapter discusses water as an environmental factor and the blood as transporter of respiratory gases. Further chapters treat the anatomical and histological structure of the gills and their function as respiratory organs, embryonic respiration, the functions of auxiliary breathing organs such as the skin, membranes of the mouth and throat (air respiration of the labyrinth fishes and of *Amphioxus* and *Electrophorus*), intestines, and swimming bladder. Those remarkable specimens, the lung fishes, Polypterids and Dipnoi receive discussion. The concluding chapter deals with the function of the pseudobranchia, the acidophile cells in all the breathing organs of fish, and the gland cells of the swimming bladder. The bibliography comprises 313 titles.

FOOD CONSUMPTION OF CHILDREN AT THE NATIONAL CHILD RESEARCH CENTER. *U. S. Department of Agriculture. Circular No. 481.*

By Helen Nebeker Hann and Hazel K. Stiebeling. Government Printing Office., Washington. 10 cents. 9⅛ x 5⅝; 34; 1938 (paper).

In order to obtain data on the food-consumption habits and the nutritive value of diets of healthy young children, quantitative studies of the food consumed by children at the National Child Research Center, Washington, D. C. were made during the period 1931–36 on children from 24 to 71 months old. The authors report on the type of food served at school, the quantity of various foods eaten, the energy value of the food consumed by the children at home and in school, the nutritive value of the meals served at the nursery school, the distribution of calories among specified classes of food, and the cost of the food served at the nursery school. Frequent tables, an appendix, and a bibliography supplement the text.

SYPHILIS. *Presented by the Section on the Medical Sciences. Publications of the American Association for the Advancement of Science No. 6.*

Edited by Forest R. Moulton. The Science Press, Lancaster, Pa. $2.50. 10¼ x 7¾; 193; 1938.

The third of the symposia on public health

problems organized and presented by the Section on Medical Sciences of the A. A. A. S. is devoted to the study of syphilis, one of the most serious health problems in the United States. This symposium consists of thirty papers by thirty-two authors, all of whom are leading specialists in the various fields connected with the study of this disease. In its entirety, this publication presents an excellent systematic summary of the present knowledge of syphilis.

SCHAFER'S EXPERIMENTAL PHYSIOLOGY. *Sixth Edition.*

By W. A. Bain. Longmans, Green and Co., New York and London. $2.40. 8½ x 5½; viii + 184; 1938.

In this edition a good deal has been added to the sections on involuntary muscle, the heart, the circulation, and the special senses. The text, which contains precise directions for performing most of the fundamental experiments in physiology except those of a chemical nature, has been thoroughly revised.

A GUIDE TO HUMAN PARASITOLOGY *for Medical Practitioners. Third Edition.*

By D. B. Blacklock and T. Southwell. William Wood & Co., Baltimore. $4.00. 9½ x 6¼; viii + 259 + 2 plates; 1938.

In general this text (with the exception of being brought up to date) remains in the same form as the earlier edition. The chapter on malaria has been entirely rearranged and the section on leishmaniasis largely rewritten.

BIOCHEMISTRY

INSULIN: *Its Chemistry and Physiology.*

By Hans F. Jensen. The Commonwealth Fund, New York; Oxford University Press, London. $2.00. 9 x 5⅞; xii + 252; 1938.

A concise but comprehensive review and evaluation of most of the important literature on the chemistry and physiological action of insulin. Since a vast literature has accumulated in this field of research, the author has given preference to the more recent researches on insulin and has recorded literature up to January 1, 1938.

The monograph is divided into seven chapters, each concluding with an extensive bibliography, and dealing in the following sequence with: (1) the history of insulin including early investigations on the relationship between the function of the pancreas and diabetes and early attempts to prepare pancreatic extracts; (2) the methods of preparation and purification of insulin and sources of insulin in tissues other than the pancreas; (3) the preparation and chemistry of crystalline insulin starting from 1926 when Abel and his associates first obtained the hormone in its crystalline form and demonstrated its protein-like nature; (4) the standardization of insulin; (5) the different modes of injecting insulin; (6) the many insulin substitutes and their therapeutic value; and (7) the physiological action of insulin. The investigations made by the author and his associates in the chemistry of insulin are included in this book.

DIE ELEKTRISCHEN GRUPPEN IN BIOLOGIE UND MEDIZIN (*with an English Summary*).

By Rudolf Keller. Sperber-Verlag, Zürich. 3 francs. 9¼ x 5¾; 92; 1938 (paper).

This brief résumé of some of the literature on electrical analyses of human organs and tissues in health and disease was prepared in the hope of encouraging further work, and of interesting chemists, physiologists, and medical men in the study of measurements of electric qualities of the minerals of body tissues as an aid to diagnostic work. Some diseases are claimed to be due to an upset of normal electric balance. From this point of view individual chapters—some but two pages in length—treat pregnancy, minerals of the eye, the kidneys, nerves, blood, invisible circulation in the connective tissues, etc. The book is documented and there are appended a brief literature list and a quotation in English of Franz Goldmann's (Prague) "The importance of the mineral groups for the understanding of physiological and pathological states during infancy."

GRUNDISS DER HISTOPHYSIOLOGIE. *Allgemeine Methoden und Probleme. Probleme der Biologie, Band 2.*

By Erich Ries. Akademische Verlagsgesellschaft, Leipzig. 26 gold marks. $8\frac{1}{2}$ x $5\frac{3}{8}$; xii + 413; 1938.

This, the second volume of the *Probleme der Biologie* series, brings together and correlates (1) the various methods of histological technique, and (2) the differentiation, behavior, and properties of cells and tissues *in vivo* and *in vitro*. Some problems such as the permeability of the membranes, the germ cells and fecundation are treated summarily, whereas vital straining, histochemistry and the physicochemical techniques receive more space. The bibliography covers 45 pages, and there are author and subject indices.

THE DETERMINATION OF THE AMINO ACIDS. *Revised Edition.*

By Richard J. Block. Burgess Publishing Co., Minneapolis. $2.00. $10\frac{3}{4}$ x $8\frac{1}{2}$; [8] + 91; 1938.

It is the author's opinion that of the 22 recognized amino acids only the following 12 can be estimated with a fair degree of accuracy: arginine, cystine, glycine, histidine, diiodotyrosine, lysine, methionine, phenylalanine, proline, thyroxine, tryptophane and tyrosine. In the second printing of this monograph corrections of errors in the first edition and modifications of some of the descriptions of methods have been made.

BIODYNAMICA. *A Journal for the Study of the Nature of Life (Structure and Dynamics of Living Matter). Nos. 34–37 and 38–43. Edited by Basile J. Luyet. Biodynamica, Normandy, Missouri.* $9\frac{3}{4}$ x 7; Nos. 34–37, 60; Nos. 38–43, 56; 1938 (paper).

SEX

PLAN FOR MARRIAGE. *An Intelligent Approach to Marriage and Parenthood. Proposed by Members of the Staff of Vassar College.*

Edited by Joseph K. Folsom. Contributors: Mary S. Fisher, Beatrice B. Berle, J. Howard Howson, Joseph K. Folsom, Raymond Squier, Ruth E. Conklin, Gladys B. Jones. With a Foreword by Henry N. MacCracken. Harper and Brothers, New York and London. $3.00. 8 x $5\frac{1}{4}$; xii + [2] + 305; 1938.

For various and well-known reasons, sex behavior in general has only in recent years become the subject of more or less open discussion. Lately the movement which seeks to spread accurate knowledge about the several aspects of the interrelations between the sexes has reached the schools and in some colleges courses on marriage have become a more or less established part of the curriculum. One of the most publicized of these is that given at Vassar College and in this book the seven teachers responsible for it present the substance of their lectures. M. S. Fisher contributes three chapters dealing respectively with the place of romance in love and marriage, the employed married woman and parenthood. Three other chapters have been written by J. H. Howson who deals with the questions of intelligence, emotional maturity and religion in relation to marriage. The editor, J. K. Folsom, in two chapters, writes on marital selections and the future of the marriage institution. B. B. Berle, G. B. Jones, R. Squier, and R. E. Conklin have each contributed a chapter. The technique of intra-marital harmony is discussed by the first, the budget by the second writer, sex physiology is outlined by the third writer, and the fourth summarizes what is known about the anatomy and physiology of reproduction. Altogether, this volume demonstrates the competence of the writers but the chapters prepared by the last three named stand out. The reason is obvious. They concern phenomena about which there is a certain amount of real knowledge. The same cannot be said about the aspects of marriage treated in the other chapters; consequently these articles smack too much of the sermon and convey the personal ideals of the writer rather than objective information about the matter.

PRACTICAL BIRTH-CONTROL METHODS.
By Norman E. Himes, with the medical collaboration of Abraham Stone. Introduction by Robert L. Dickinson. Foreword by Havelock Ellis. Illustrations by Irving Geis. Modern Age Books, New York. 95 cents. 8 x 5½; [14] + 254; 1938 (paper).

The purpose of this manual is to help the individual seeking contraceptive advice to find a competent doctor and to supplement the oral instructions he (or maybe she, says Reginald the Office Boy) will obtain with printed information enabling the more intelligent application of such instructions. Himes aims to present certain general information too detailed for a doctor to offer in an interview, but calculated to allay unnecessary fears resulting from insufficient knowledge of sexual matters.

In this complete, thorough, and well-written volume the author, with the medical collaboration of Dr. Abraham Stone, has succeeded admirably in accomplishing his purpose, and deals in a scholarly fashion, though not without humor, with all the pertinent information. The medically approved methods used today are separately described, evaluated and illustrated by accurate and simplified drawings. A valuable chapter on Household Methods has been added for the benefit of those living in rural districts inaccessible to medical help. The dangers of harmful, ineffective and much advertised methods of Feminine Hygiene are pointed out, and the fundamentals of sex anatomy and physiology are briefly and clearly discussed.

An historically interesting chapter is that on primitive methods of birth control, while other chapters give brief histories of its more modern crusaders and discuss the steps that have been taken to modify the legal attitude toward birth control in the United States. Further chapters discuss sterilization, abortion and the Russian experiment. Appendices include a list of the United States birth control-centers according to states, a list of the trade names of approved contraceptives, and a glossary. Also included is a complete index and suggestions for further reading.

THALASSA: *A Theory of Genitality.*
By Sàndor Ferenczi. Translated by Henry A. Bunker. The Psychoanalytic Quarterly, Albany, N. Y. $1.75. 9 x 6; v + 110; 1938.

In this book a psychoanalytic interpretation of the act of coitus in human beings is presented. The subject matter, an outgrowth of reflections by the author, is developed in three sections. The first section is concerned with the ontogenetic significance of coitus, the thesis being that each act of coitus is basically a symbolic return of the male, and of the female through identification with the male, to intrauterine existence. The second section advances a phylogenetic interpretation of coitus, namely that each act of coitus in reality represents a return of the individual to that period in evolutionary history before the recession of the ocean, when life was essentially aquatic. In the final section the possibility of the origin of the two sexes as an adaptation to land life is discussed from the psychoanalytic viewpoint. The author's argument appears to be something less than quite incontrovertible, but will be of interest to psychiatrists as an example of psychoanalytic reasoning.

DER ZYKLUS DER FRAU. *Reform des Ehelebens.*
By Jules Samuels. G. Naeff, The Hague. Gld. 4.50 (paper); Gld. 5.50 (bound). 9¾ x 6¼; 174; 1938.

The author here describes and explains the mechanism and operation of the cycloscope—the principal part of which is a spectroscope—perfected by him in 1937, and reputed to (a) determine exactly the date of ovulation in women; (b) to diagnose within a few days after the event, the fertilization of an ovum; and (c) to present graphically all ovulatory and menstrual variations. His results, also presented in this book, oppose the current "safe-period" theories in that the cycloscopic studies support the theory that ovulation in the human female occurs twice (and sometimes even three times, especially in young nullipara) during the menstrual cycle, the first usually occurring

on the ninth to twelfth day, and the second on the sixteenth to eighteenth day. The "fertile period" is therefore given as from the third day before the first ovulation to three days after the second.

The publications of the author on this subject—25 articles and three books from 1937 on!—alone serve as bibliography.

CONTROL OF CONCEPTION. *A Clinical Medical Manual. Second Edition.*

By Robert L. Dickinson. Williams & Wilkins Co., Baltimore. $3.50. 9 x 6; xiv + 390; 1938.

Dr. Dickinson's name alone appears on the cover of the revised edition (cf. Q.R.B., Vol. 7, No. 3 for mention of first edition) of this standard and valuable manual. When compared with the earlier editions we note a good many changes in the drawings and arrangement of subject matter and the addition of much new material. A number of special contributors have written on such subjects as hormonal control, sperm immunity, and the "safe" or sterile period, and the results of important recent studies have been incorporated in many sections of the book. An excellent guide for the teaching and practising physician.

CONTRIBUTIONS TO FATE ANALYSIS. I. *Analysis of Marriages. An Attempt at a Theory of Choice in Love.*

By L. Szondi. Martinus Nijhoff, The Hague. Gld. 2.80. $9\frac{3}{4}$ x $6\frac{5}{8}$; 80 + 7 plates; 1938 (paper).

This book is offered as the first in a series designed to elevate "erology" or the science of love, to a place among the exact sciences. The author advances the theory that attraction between individuals is strictly the result of the possession by each of common recessive ancestral genes which act as "natural matchmakers." This argument seems rather naively conceived, and is not very convincingly supported by the case records and geneological data which the author presents. There is no index or bibliography.

BIOMETRY

STATISTICAL METHODS FOR RESEARCH WORKERS. *Seventh Edition, Revised and Enlarged.*

By R. A. Fisher. Oliver and Boyd, Edinburgh and London. 15s. $8\frac{3}{4}$ x $5\frac{3}{4}$; xv + 356; 1938.

Professor Fisher has made two changes in this latest edition of his well-known text which should be noted. The section on "Fitting of curved regression lines" has been expanded so as "to give a fuller introduction to the theory of orthogonal polynomials, by way of orthogonal comparisons between observations"; and in the chapter on analysis of variance, a new section dealing with the discrimination of groups by means of multiple measurements has been added. The numbers of sections, tables and examples have been unaltered by the insertion of fresh material, so that references to them are valid for all editions.

INTRODUCTION TO ECONOMIC STATISTICS.

By William L. Crum, Alson C. Patton and Arthur R. Tebbutt. McGraw-Hill Book Co., New York and London. $4.00. 9 x $5\frac{3}{4}$; xi + 423; 1938.

A complete revision of an excellent book which first appeared in 1925 (cf. Q.R.B., Vol. 1, p. 135). New parts have been added and certain "materials which appear now appropriate for more advanced texts have been eliminated or reduced in emphasis. The intent throughout has been to preserve the elementary character of the treatment." The sections of the book are as follows: Statistical data; general and analytical methods; the analysis of time series; a group of 4 appendices, and an index.

STATISTICAL METHODS *Applied to Experiments in Agriculture and Biology.* [*Revised.*]

By George W. Snedecor. Collegiate Press, Inc., Ames, Iowa. $3.75. $8\frac{7}{8}$ x $5\frac{7}{8}$; xiii + 388; 1938.

This edition follows very closely the original (noticed in Q.R.B., Vol. 13, No. 3) except that either by elimination or con-

densation of material it is shorter by 46 pages. The brief time between the appearance of the two editions indicates the usefulness of this text.

PSYCHOLOGY AND BEHAVIOR

THE REDISCOVERY OF MAN.
By Henry C. Link. The Macmillan Co., New York. $1.75. $7\frac{3}{4}$ x $5\frac{1}{4}$; ix + 257; 1938.

Here is a book which many will wish to read, but few will wish to own; which many will discuss but few remember.

The author is a practical psychologist, which means that he treats psychiatric cases, but he does not call himself a psychiatrist for he reserves that term for those who have had medical training. This does not imply that the author has had no medical training, but only that he does not believe a knowledge of medicine necessary to a successful treatment of psychiatric cases.

Link believes that there are two contrasting types of personality—the introvert and the extrovert. In concrete instances these two are mixed in varying proportions. The value of any influence is to be determined by the type of personality to which it ministers. Influences that make for introversion are bad and should be avoided, while those that make for extroversion are good and should be cultivated. Thus bridge is a good game because it involves four participants, and chess is a bad game because it involves only two. Orchestral music is good, because it involves an entire orchestra, but the piano is an independent instrument and its use should be discouraged except as an instrument of discipline.

As the present reviewer reads this book, he becomes increasingly aware that his own personality embodies practically all those traits that Dr. Link considers objectionable, and so enters upon his task with a certain amount of prejudice which readers should bear in mind when discounting his conclusions. Yet the reviewer must admit that the author hits the nail on the head with somewhat greater frequency that one would expect were his aim controlled by mere chance. Perhaps he was aiming at a different nail. He is at his best in matters of absolute theology—his discussion of the character of Jesus in his closing chapter is both sound and sane—one wonders why it was not placed at the beginning of the book. But when he comes to the application of the example of Jesus to modern problems of social misplacement he seems to go sadly astray.

The social misfit is personality that is not adjusted to its environment. The adjustment may, in theory, be made either by altering the personality or the environment. But as the environment contains many personalities, and is therefore more complex than any individual personality, Link believes the adjustment can be made more expeditiously by altering the personality, and calls the practice of Jesus to witness. It is true that Jesus did work profound changes in personalities of those with whom He came into intimate contact, but it is clear that many of these were to meet emergencies (i.e., the healing of the lepers and the man with the palsy and the casting out of devils) and He made no use of these in His teaching—in fact in one instance He enjoined his patient to say nothing of what had occurred. The oft-quoted statement "Ye must be born again" was only a means to an end—it was addressed not to the social misfits, but to those who considered themselves in complete adjustment. Had all of these been spiritually reborn a rather revolutionary change in the environment would have been the result.

Of course, the value and efficacy of Dr. Link's treatment must be judged by the results obtained in practice and not by theories expounded in books, and it may well be that his practice is superior to his theory. But one cannot help feeling that his philosophy is dangerously near to the pessimism of John Vance Cheney, who implies that the System was not made for man, but that man was made for the System, as in his poem inspired by Millet's painting "The Man with the Hoe" when he declares that the laborer was

> Cast for the gap, and gnarled in arm and limb
> The mother molded him.
> Yes, since above his work he cannot rise
> She makes the fields his skies.

PERSONALITY STRUCTURE IN SCHIZOPHRENIA. *A Rorschach Investigation in 81 Patients and 64 Controls. Nervous and Mental Disease Monograph No. 63.*

By Samuel J. Beck. Preface by C. Macfie Campbell. Nervous and Mental Disease Publishing Co., New York. $2.00. 9 x 6; ix + 88; 1938.

This book presents the results of a study of 81 schizophrenic patients at the Boston Psychopathic Hospital and 64 non-psychotic controls by means of the Rorschach ink-blot test. The nature of the test, the procedure for administering it, the method of scoring the patient's responses, and sample responses of patient and control form the subject matter of the first four chapters. The statistical findings in the material of this study are then presented and the psychological implications discussed. The author feels that the Rorschach test is valuable not only as an objective aid in differential diagnosis, but also in elucidating the structure of the schizophrenic personality. Some of the conclusions to which test results lead in this respect are presented in the remaining chapters. It was found that, relative to the controls, the schizophrenic patient stands significantly lower in appreciation of reality, significantly higher in affect, with not much difference in grasp of relationship and in imaginative living.

This study is a valuable contribution to the problem of the schizophrenic personality, both as a demonstration of the possibilities of the Rorschach technique and in the specific conclusions emerging from its application in this particular sample of schizophrenic patients. There is an index and a brief bibliographical note.

MODERN SOCIETY AND MENTAL DISEASE.

By Carney Landis and James D. Page. Farrar and Rinehart, Inc., New York. $1.50. 8 x 5¼; xi + 190; 1938.

In this excellent book, written from the biosocial viewpoint, the authors have utilized data obtained from public records in this country and in Europe, as a basis for studying the relationship of mental disease to such important factors as sex, age, education, economic status, social status, and environment. Such controversial questions as marriage, eugenics, and sterilization in relation to mental disease are considered in a practical way. The interesting conclusion is reached that if the two groups of mental patients in which hereditary factors seem to operate to some extent (manic-depressive and dementia praecox) were sterilized at the time of first admission to hospital, the incidence rates for the former would be reduced only from 1.1 to 2.4 percent in the next generation, and for the latter from 2.2 to 3.3 percent. The material in this book supports the argument that etiologic factors in mental disease are basically physiological and constitutional rather than psychological. Interesting data are likewise presented on outcome of mental disease and on the increasing incidence of mental disease. There is an appendix and a bibliography of 115 titles.

THE BEHAVIOUR OF ANIMALS. *An introduction to its Study. Second Edition.*

By E. S. Russell. Edward Arnold and Co., London; Longmans, Green and Co., New York. $4.20. 8½ x 5½; viii + 196 + 6 plates; 1938.

The second edition of this work is practically unchanged from the previous edition (noticed in Vol. 9, No. 4). One new chapter has been added, however, wherein Russell emphasizes the point that

> the animal's perceptual world is essentially a practical or functional one. The animal attends to, perceives, and shows behaviour in respect of, only those events, objects, and characters of objects that are at the moment functionally important to it, those about which it is impelled *to do something*; only these have valence for it. All other features of the environment, which come within its sensory range, constitute what we may call the neutral background of action, and in so far, and at such times, as they are not responded to or dealt with in any way, they must be regarded as not perceived, as having no valence.

This is still one of the best of works to serve as an introduction to the study of animal behavior.

LIFE AND GROWTH

By Alice V. Keliher, with the Commission on Human Relations. D. Appleton-Cen-

tury Company, New York. $1.20. 7⅞ x 5; x + 245; 1938.

This book, written for those of high-school and junior-college age and based on a collection of questions asked by the young and assembled by parents and teachers, contains a miscellany of sociology, psychology and physiology. Part One, Human life and social progress, discusses both old ideas and modern scientific ones, intelligence and intelligence testing, pointing out errors in thinking and emphasizing the psychological needs of the individual. Part Two gives some of the fundamentals of heredity, the body and its functions, including an outline on the work of the endocrine glands. An important and skillfully handled section deals with the problem of sex development and sex functioning.

Illustrated by amusing pictorial graphs and photographs, the volume includes suggestions for further reading, a glossary and a complete index.

THE PUPILLARY RESPONSE CONDITIONED TO SUBLIMINAL AUDITORY STIMULI. *Psychological Monographs, Vol. 50, No. 3, Whole No. 223.*

By Lynn E. Baker. Psychological Review Co., Ohio State University, Columbus. 50 cents. 9¾ x 6¾; v + 32; 1938 (paper).

Some of the results of this interesting experimental study are as follows:

> "The pupillary response can be conditioned to a subliminal auditory stimulus." . . . "The conditioning is accomplished in two stages" . . . "the conditioned *disturbance* response" [and] . . . "the *final form* response." . . . "The conditioned connection is more easily established when the conditioned stimulus is subliminal than when it is supraliminal." . . . "The conditioned pupillary response is specific to a high degree." . . . "The *disturbance* response is less specific than the *final form* response."

Tables and graphs are given in the text and the paper concludes with 16 references to the literature.

FOX IN THE CLOAK.

By Harry Lee. Macmillan Company, New York. $2.50. 8⅜ x 5⅜; 557; 1938.

Apart from its interest as a good story, this novel deserves the attention of human biologists as a penetrating and significant study of adolescence, and of the behavior responses in that period of life to the bewildering and painful stimuli that pour in from the social and the physical environment.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

GENERAL SEMANTICS. *Papers from the First American Congress for General Semantics Organized by Joseph C. Trainor and Held at Ellensburg, Washington, March 1 and 2, 1935. With an Introductory "Outline of General Semantics" by Alfred Korzybski, and Other Related Contributions.*

Collected and Arranged by Hansell Baugh. Arrow Editions, New York. $2.00. 11 x 8; 111; 1938 (paper).

The most significant chapter in this symposium is the opening introduction by Korzybski, for one can hardly appreciate a synthetic work of this sort on semantics unless one has some idea as to the signification of this word, and the science of semantics is as yet too young for its name to have become a household word.

Korzybski's thesis is that language is the result largely of environmental contacts, and as man becomes better acquainted with the factors of his environment his language must undergo corresponding modification. But the growth of language is always inordinately slow, so that it lags behind the need that called it forth. As a result, it lacks exactitude, and consequently its elemental terms have different meanings for different people. To a man like Korzybski who speaks fluently five European languages and has probably a working knowledge of several more, the different shades of meanings are more obvious than to one who finds a single language sufficient for his needs. Such an idiom as the double negative in Spanish whose meaning is just the opposite of its literal English translation, or the English phrase "nothing less than" which undergoes a similar reversal of meaning in German are apt illustrations. A friend of the reviewer who was recently driving through Georgia was informed

that he would find the road to be slick, and taking this word to have the same meaning as in his own Colorado, he essayed to negotiate the road, but learned to his dismay that slick in Georgia means not good, but slippery. And how many who are not native Philadelphians know what it means to have a concern, or a stop in the mind?

It is Korzybski's belief that all misunderstandings between individuals as well as between nations result from inexactitude in the meaning of terms, and he longs for a language with the precision of mathematical symbols, so that it will not be necessary to resort to the language of Aristotle and Euclid in discussing the physics of Planck and Einstein. He even goes so far as to venture that many cases of mental derangement due to maladjustments of society might be corrected by the study of semantics, and that the reason that every philosopher appears to have his own peculiar system is due to the ambiguous jargon to which such writers are addicted. They are masters of language in the sense that Lewis Carroll's Humpty Dumpty was, when he declared "When I use a word, that word means exactly what I want it to mean."

The reader will be inclined to speculate as to whether semantics is to become a permanent department of science, or whether it is to share the fate of technocracy, midget golf, Leo Ornstein, diabolo, and Donati's comet. The reviewer is inclined to the former opinion, for the latter enumerated items, with the exception of the last, were talked to death by the Areopagites, and then buried when the novelty had worn off. But the Areopagitic mind is not likely to comprehend semantics.

On the other hand, it must not be forgotten that the art and literature of the ages, and most of the humor as well, has been made possible by the use of idiomatic verbal expression. If we are not satisfied with the way Toscanini interprets a symphony, we are at liberty to listen to Damrosch, Stokowski, or Marcelli. A symphony expressed in mathematical symbols so that all interpretations were exactly alike would *ipso facto* have no interpretations at all. The only composer to attempt to express his compositions in this form was Euler, but it is as a mathematician and not as a symphonist that the world has chosen to remember him. Yet the advantages of an exact language in which every term shall have one and only one signification and in which no two terms shall have the same signification are obvious. Perhaps ultimately it will be found necessary for every one to know two languages—one for science and one for art.

SCIENTISTS ARE HUMAN.

By David L. Watson. With a Foreword By John Dewey. Watts and Co., London. 7s. 6d. $7\frac{3}{4}$ x 5; xx + 249; 1938.

This book is a condensation of a much longer manuscript that may be obtained in its entirety in microfilm form from the American Documentation Institute. The author himself plainly regards it as an important *magnum opus*. There is justice in this viewpoint because he has literally and honestly put a great part of himself into it. The world's estimate of its significance will probably be in some degree less high, as has not infrequently happened in parallel cases.

The central thesis of the book is, in essence, that a man's scientific work (and, of course, the same is true of everything else he does) is in some degree influenced and colored by the circumstances of his life. To the human biologist this is so obvious a truism that his first reaction is of wonder that 249 pages are necessary to discuss it. Watson's answer is that, in practical fact, not enough attention or weight has been given to this truism in evaluating the work of particular scientific men, or in adequately assessing the significance of science in the life and affairs of humanity generally, or in the organization and conduct of the enterprise of science. There can be no doubt that he has a *prima facie* case on each and all of these counts, and makes it with a good deal of skill and cleverness. But only a certain naivete would suppose scientific men generally do not know quite as well as Watson (or perhaps even better be-

cause more experienced) that some eminent scientists are merely stuffed shirts; that some others are dishonest crooks; that in science as well as in literature, art, or any other human enterprise the correlation between worldly success and intrinsic merit is something less than perfect; or that science or universities have not yet achieved the kind of organization that will automatically ensure that all degrees of genius wherever embodied in human corporeality shall have just and adequate opportunities for realization, expression, and fulfillment. Alas, all these imperfections of the sad world to which we are bound are only too well and widely known—so well understood, in fact, that most men decide that the job of rectification of so sorry a scene is too much for them. Watson is, in contrast, a crusader. We incline to the view that just as it was a mistake for her contemporaries to underrate St. Jeanne so it would be unwise for scientific men not to read *Scientists are Human* now. Apart from, and in addition to, its *Tendenz* the book has intrinsic merits. The long Chapter VI "On the similarity of forms and ideas" is a valuable contribution worthy of the most careful study.

The thing our sympathetic and friendly feelings towards the book and its author make us most deplore is a certain note of bitterness that creeps in here and there. This does not help the cause that Watson is promoting. He and his ideas are too big to toy with pettinesses.

MODES OF THOUGHT. *Six Lectures delivered in Wellesley College, Massachusetts, and Two Lectures in the University of Chicago.* *By Alfred N. Whitehead. The Macmillan Co., New York.* $2.50. 7½ x 5; viii + 241; 1938.

It is well known that where copper occurs in nature both in the native state and also in chemical combination it may be recovered more economically in the latter form, for the labor necessitated by the extreme hardness of native copper is greater than that required to decompose copper salts. A rough parallel may be drawn between the processes of separating pure copper and pure philosophy from their matrices.

Whitehead's philosophical writings are all very highly concentrated—so much so that it is harder to comprehend his philosophy than it would be if it were adulterated with science, art, or religion as so much modern philosophy is. The reader who is accustomed to the assimilation of philosophical literature must continually sharpen the edge of his intellect while reading this book; the reader who is not had best not essay it.

The most characteristic trait of Dr. Whitehead's philosophy is well illustrated by a quotation:

> . . . our bodies lie beyond our individual existence. And yet they are part of it. We think of ourselves as so intimately entwined in bodily life that a man is a complete unity—body and mind. But the body is part of the external world, continues with it. In fact, it is just as much part of nature as anything else—a river, or a mountain, or a cloud. Also, if we are fussily exact we cannot define where a body begins and where external nature ends.

In other words, he aligns himself with the dualists of the past who believed that the great cleavage plane of nature was between mind and body, and opposes himself definitely to the monists of the present who regard mind and body as constituting an indivisible organism, and who find the great cleavage plane to be between the organism and its environment. The philosophers whose writings appear to have had the greatest influence in molding Whitehead's thought have been Plato, Descartes, and Leibniz, but this does not mean that he subscribes blindly to all their dicta. Being a man of independent thought he does not hesitate to point out wherein he disagrees with these thinkers.

The book is very inadequately indexed.

SCIENCE FOR THE CITIZEN. *A Self-Educator based on the Social Background of Scientific Discovery.* *By Lancelot Hogben. Illustrated by J. F. Horrabin. Alfred A. Knopf, New York.* $5.00. 9½ x 6½; xiii + 1082 + xix; 1938.

During the past few years a great many

books have appeared in which a single writer has attempted to cover the entire field of science. Many of these attempts have been disappointing but the present one is an exception. Because Hogben has attempted not so much to popularize science as to systematize it, he has accomplished both these ends. Not a little credit for his success is due to the 480 well-executed drawings by Horrabin.

A recent reviewer has criticized this book adversely because it contains no discussion of modern relativity physics. The student who already knows enough of relativity to realize how much he does not know is likely to feel disappointment at this omission, but the present writer feels that one might as well criticize Hogben for not having produced an Encyclopedia Brittanica single handed. Perhaps later he will. Every treatise of this sort must omit much that some people will miss, in order to keep it within reasonable bounds, both as to bulk and cost. The student who assimilates all that this work contains about classical physics will be all the better prepared for relativity later.

The part of the book dealing with the biological sciences is not quite up to the standard of the rest of it, but again in any work some chapters are better than others. The ample index covers 18 pages.

VAN NOSTRAND'S SCIENTIFIC ENCYCLOPEDIA.

D. Van Nostrand Company, Inc., New York. $10.00. 10½ x 7¼; 1234; 1938.

Over ten thousand scientific terms covering the fields of aeronautics, astronomy, botany, chemistry, engineering, geology, mathematics, medicine, minerology, navigation, physics, and zoology are explained concisely and interestingly by authorities on the respective subjects. Although a number of men in each field have contributed articles or acted in an advisory capacity, the responsibility for the treatment of each science has rested largely on a single person, thereby insuring greater unity than is usually possible when a great many persons contribute. The persons in charge of the items in the biological sciences include Profs. A. W. Lindsey of Denison University, Hempstead Castle of Yale University, H. O. Elftman of Columbia University, R. S. Mueller of the College of Physicians and Surgeons, Columbia University, and R. M. Field of Princeton University.

Cross-references are indicated in the text by the use of bold-face type, thereby enabling the reader readily to find all the facts that bear on each topic included in the book. The topics are listed alphabetically, irrespective of the science. The print is good, the binding sturdy, and many illustrations are included.

BACKGROUND TO MODERN SCIENCE. *Ten Lectures at Cambridge arranged by the History of Science Committee 1936. Edited by Joseph Needham and Walter Pagel. The Macmillan Co., New York; The University Press, Cambridge.* $2.00. 8 x 5½; xii + 243; 1938.

This book is a reproduction of the inaugural course of lectures on the history of science presented at Cambridge in 1936. During the course, ten different eminent scientists gave accounts of the development of their particular fields of interest, and as a consequence, the volume is essentially a treatise on the foundation of modern scientific theories.

The early chapters by Cornford and Dampier deal with the development of scientific thought from the natural philosophy of the Greeks to the new conception of the cosmos by Copernicus and Galileo. The later chapters are concerned with the development during the past 40 years in the fields of physics, astronomy, physiology, biology, evolution and genetics.

An amazing amount of material is incorporated into each chapter, making the entire volume extremely meaty yet thoroughly readable and enjoyable. Every present-day biologist should steal enough time from his regular tasks to read *Background to Modern Science.*

THE POEMS OF RICHARD DE VEAUX. *Privately Printed, Baltimore, Maryland.* 10 x 7; 82; 1938.

Richard De Veaux was the *nom de plume* of Mrs. Ethan Allen Andrews (born Sara Gwendolen Foulke). She achieved fame as a biologist in her own right through the remarkable study published in 1897 under the title *The Living Substance*. Shortly after her death Professor Andrews brought all her poems together in this beautiful volume for private distribution to friends. The poems cover a wide range of thought, feeling, and style. Some rise to heights of great and poignant beauty; others, and especially those written for her children, are completely charming in their light and graceful wit.

Altogether this volume seems the perfect memorial tribute to a remarkable woman.

COLOR PHOTOGRAPHY FOR BEGINNERS.
By Robert M. Fanstone. Camera Craft Publishing Co., San Francisco. $1.50. 7¼ x 4⅝; 136; 1938.

With careful use this little volume will undoubtedly lead the beginner in color photography to a satisfying amount of success in his fascinating hobby. The few books on the market which deal with the subject of color photography have been published more for the professional photographer than for the beginner, and for this reason there has been a real need for just the type of book here produced. The text contains a brief discussion on the principles of color photography, together with a presentation of the salient factors regarding apparatus, materials, and the processes of exposing, developing, and finishing the colored pictures.

The volume is rather sparsely, though beautifully, illustrated by a group of well-chosen polychrome photographs. There is an appendix of Makers' Formulae and a complete index.

THE MODERN QUARTERLY. *Volume 1, Number 2.*
Lawrence and Wishart, London. 2s. 6d. 9¾ x 6; 103–207; 1938.

A variety of subjects have found their way into this journal which sets itself to defending materialism and opposing reactionary tendencies, such as Fascism, which lead to "degeneration of thought and culture."

Among the articles is a study by J. B. S. Haldane on haemophilia in the royal families of Europe. It is interestingly and simply written, and would not only appeal to the lay reader, but at the same time give him a smattering of genetic knowledge. Another paper deals with the functions of literature and art as psychological propaganda for the creation of faith in national socialism, thus leading to deterioration of culture. Further articles present an evaluation of food consumption in Germany; a study of the history of writing and mathematical knowledge; and The creed of a dialectical materialist which is a verbose argument against use of the abstract and could well have been omitted.

THE SCIENTIST IN ACTION. *A Scientific Study of His Methods.*
By William H. George. Emerson Books, New York. $3.00. 8½ x 5⅜; 354; 1938.

The American edition of this book, with the exception of the preface, is the same as the English edition which was reviewed in this journal in Volume 12, Number 2, page 245.

PROFILES IN HUMAN BIOLOGY. III AND IV

By RICHARD RICHARDSON

III

THE INFANTRY INSTRUCTOR

HE IS an officer and a gentleman,
But hardly a scholar.
It is most unfair
To smile at his uniform,
For there is a current tale
That it was designed
By some tailor at Whitehall
After a wild night at sea.

Should you tell him
That the medieval bowmen
Twisted their arrow points
To make wounds fester,
That negroes were inoculated with small pox
In our Revolution
To carry disease to the enemy,
That we used pump-guns and bear-traps
With effectiveness
In the Late Unpleasantness,
Though indignantly protested
By the enemy,
He is bored.
For he is an officer and a gentleman—
Not a scholar.
And he does not seem to know
That the sole end of war
Is to win—
For defeat
Is suicide
And hence
Approaches mortal sin.
(A nice point
Made by
Saint Thomas Aquinas
Some seven centuries ago.)
He may have heard of Clausewitz and Napoleon—
Successful men
Without any accepted Rules
Of combat or of honor:
For the sole end of war
Is to win.

If you ask him
His function
When in action,
He would probably reply
In the terms of the mythical cavalry officer
Of the late War:
"To give tone
To what otherwise would have been
A mere brawl."
He probably has not heard
Of the gallant captain
Of the "Alabama"
Who bitterly complained
Of Commander Winslow's
Vulgar action
In lacing his ship's sides
With anchor chains

To save his gun crews.
But he would approve the protest,
For he is a kindred spirit:
An officer and a gentleman—
Not a scholar.

He is always talking about
'The man with the bayonet,"
Not knowing
That Cumberland's artillery
Ended the Scot's wild charge
And hard cold steel
At bloody Culloden
In the '46's
Near two hundred years past,
Or that bayonet wounds
Were a curiosity
In the War between the States.

His idea
Of a good shot
Is one fair through the occiput
Requiring only
A hasty burial
As compared with
A shattered knee-cap
That fills an enemy's bed
For months.

When next we fight
He will stand with his men,
Brave, cool, firm, erect,
An heroic figure
Until some sniper
Gets the range
And picks him off
At two thousand meters.
After brief but suitable
Obsequies
He will be replaced
By some realistic mechanic
From Akron,
Uncultured and ill-groomed,
Who shares
The blesséd Saint Thomas'
Contention
That the sole end of war
Is to win.

IV

CLINICAL INVESTIGATOR: TYPE III

IT WAS written in the stars
That after the Shaman,
The Pontifex,
The Fili
And the Roundhead
Would come the Clinical Investigator:
Type III.
Not all of him
Nor many of him,
But a number sufficient
To tar-brush his betters.

He is an interesting person,
And to him
Comparison,
Computations
And Controls
Are equally odious.
He has never learned the difference
Between the verbs
"Is" and "should."
Like a hagiographer,
He considers it

Good form
To always add
A few extra miracles:
And his dice
Often throw
Double Sevens.

He blights
Whatever he may touch.
But he is uncurbed, for
"His strength
Is as the strength of ten
Because his heart is pure,"
And the Public
Still regards Santa Claus
As a Prominent Person
In medical circles.
We bear with him,
Knowing that
In due time
He too
Will depart
For the march-past
Of the honest but self-deceived
Is unending.